Seeding in the Southwestern PINE ZONE

for Forage Improvement and Soil Protection

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Seeding in the Southwestern Pine Zone for Forage Improvement and Soil Protection

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THE ZONE: ITS TOPOGRAPHY, SOIL, AND CLIMATE

The ponderosa pine zone of Arizona and New Mexico covers more than 18 million acres or approximately 12 percent of the area of the two States. Elevations of its forests range from 5,500 to 8,500 feet. At the lower and drier borders, pine grows in mixture with Gambel oak,[3] pinyon pine, and juniper. With increasing elevation and moisture the pine changes to a pure stand and reaches optimum development at about 7,500 feet. Above this elevation Douglas-fir and limber pine are usually mixed with ponderosa pine. Pure dense stands of Douglas-fir are found above 8,500 feet. Spruces and true firs occur above the Douglas-fir belt and occupy the coldest, wettest, and highest forested areas.

Numerous meadows and parks of varying size occur throughout the pine forests. These support a variety of grasses and forbs that furnish valuable forage for both livestock and big game. Most abundant are the grasses: Arizona fescue, mountain muhly, pine dropseed, muttongrass, and western wheatgrass. Blue grama and squirreltail are commonly found in deteriorated areas and at the lower edges of the type. Numerous other herbaceous plants and small shrubs also occur intermingled with these grasses.

The topography of the ponderosa pine zone varies from nearly level or undulating plateaus to steep, rough mountain slopes. Soils range from sands to heavy clays. These are shallow and rocky in many places and vary greatly in depth. They are generally low in organic matter and have poorly defined profiles.

The climate of the ponderosa pine zone is favorable for range seeding (*7*).[4] The average annual precipitation varies from 18 to 35 inches and comes mainly in 2 periods. Summer rains, which are rela-

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[1] Mr. Lavin was employed by the Forest Service when the research reported here was being conducted.

[2] Central headquarters of the Station maintained at Fort Collins, Colo., in cooperation with Colorado A&M College; research in the area with which this report is concerned is cooperative with the University and State Colleges of Arizona at Tucson, Tempe, and Flagstaff; the University of New Mexico, Albuquerque; and the New Mexico College of A&M, Las Cruces. Facilities and services contributed by these institutions helped substantially in this study. The authors also wish to acknowledge contributions from the Soil Conservation Service in furnishing seed and advice; and to numerous Forest Service employees for furnishing facilities and assistance in carrying out the studies, and in preparing the manuscript.

[3] A list of common and botanical names of species mentioned appears on p. 49.

[4] Italic numbers in parentheses refer to Literature Cited, p. 50.

tively intense but of short duration, occur in July, August, and September. More gentle winter storms of several days duration occur in November, December, January, and February. Winter moisture usually falls as snow, and deep snow is common at the higher elevations.

The proportion of the annual precipitation that occurs as summer rain increases from west to east. Thus at Flagstaff, Ariz., approximately 40 percent of the precipitation falls during the summer rainy season, while in the ponderosa pine zone of central New Mexico 60 percent or more occurs during the same period. Drought is common. In almost every year plants suffer from lack of moisture in the spring and again in the fall. In addition, summer rains or winter snows, or both, are deficient enough to seriously impair plant growth and forage production 2 or 3 years in each decade.

Temperature extremes are great, commonly ranging from maximums of ±100° F. to minimums of −30°. Length of growing season varies from less than 90 days at the higher elevations to 150 days or more at the lower altitudes.

The information and seeding guides presented in this handbook are based on studies made during an 8-year period, 1945–53, in the ponderosa pine zone of Arizona and New Mexico (fig. 1). As a means of indicating artificial seeding results already attained in specific areas of the zone under varying site, elevation, precipitation, and soil conditions, names of the 1945–53 experimental areas will be used here for their reference value (table 1).

Although the experimental areas were concentrated in the northwestern and northeastern sections of the zone, approximately 200 widely distributed supplementary range seedings have provided sufficient additional information so that recommendations given are considered to be generally applicable throughout the southwestern ponderosa pine zone.

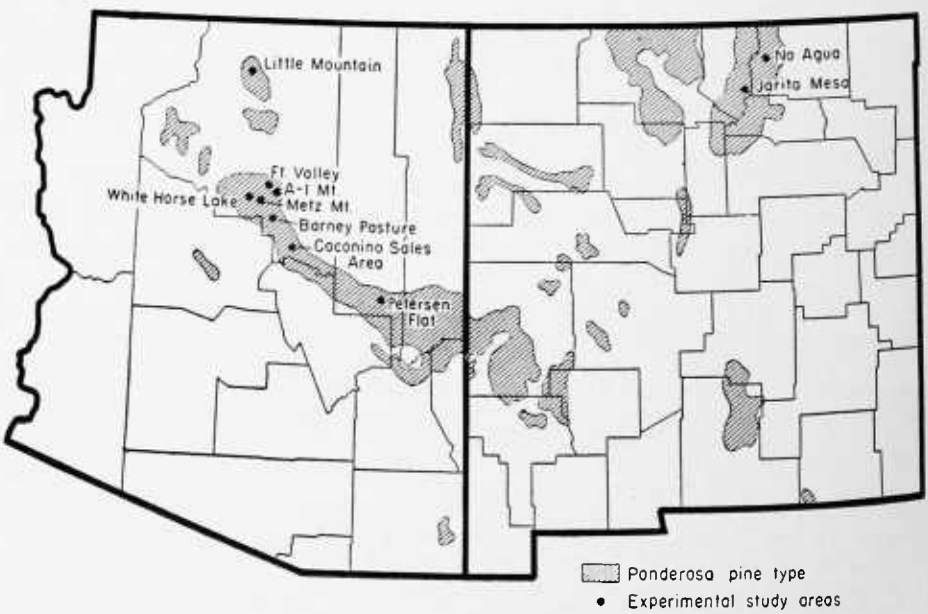

FIGURE 1.—Ponderosa pine lands in the Southwest.

TABLE 1.—*Artificial-seeding study areas in the southwestern ponderosa pine zone*

Experimental area	Site description	Elevation	Average annual precipitation	Soil type texture class
		Feet	*Inches*	
Arizona:				
Fort Valley	Natural pine opening.	7, 400	23. 2	Loam.
White Horse Lake	do	6, 900	22. 1	Clay.
Peterson Flat	do	6, 500	19. 6	Loam.
Little Mountain	Cutover pine land.	7, 700	18. 0	Clay-loam.
Coconino Sales	do	7, 100	22. 0	Loam to clay-loam.
A–1 Mountain	Pine burn	7, 300	23. 0	Loam.
Metz Mountain	do	6, 500	21. 1	Do.
Barney Pasture	do	6, 700	22. 0	Do.
New Mexico:				
Jarita Mesa	Natural pine opening.	8, 300	25. 0	Do.
No Agua	do	8, 200	18. 0	Do.

WHY SEED?

To Improve Range Condition and Forage Supply

There are now thousands of acres of deteriorated natural grassland openings in the southwestern pine forests. Many of these openings were once the most productive range areas of the ponderosa pine zone. Now, forage yields are low and erosion is severe. Because former valuable grasses have been almost completely replaced by low-value weedy vegetation, improvement through natural revegetation will be slow and costly in terms of lost productivity. Since park and meadow openings in the Southwest are usually not well adapted to tree growth, as suggested by the work of Pearson (*32*), range seeding is a practical and economical method for rapidly restoring many of these deteriorated openings to high productivity.

The reward for hastening restoration and increasing forage yields on seriously depleted openings where natural revegetation is slow is strikingly demonstrated by the following. In northern New Mexico, 2 years after seeding, crested wheatgrass [5] yielded 1,860 pounds of air-dry herbage per acre compared with only 50 pounds from heavily grazed native range in poor condition (fig. 2). Native range protected from livestock grazing for 8 years was in fair condition and improving as shown by an increase in the more valuable grasses, but still produced only 200 pounds per acre. Range protected for 23 years had a climax cover dominated by Arizona fescue and mountain muhly, and a herbage production of 1,300 pounds per acre. Other seeded areas in northern New Mexico have produced up to 15 times more than native range in poor condition.

[5] Crested wheatgrass, as used here, refers to *Agropyron desertorum*, commonly called Standard crested wheatgrass.

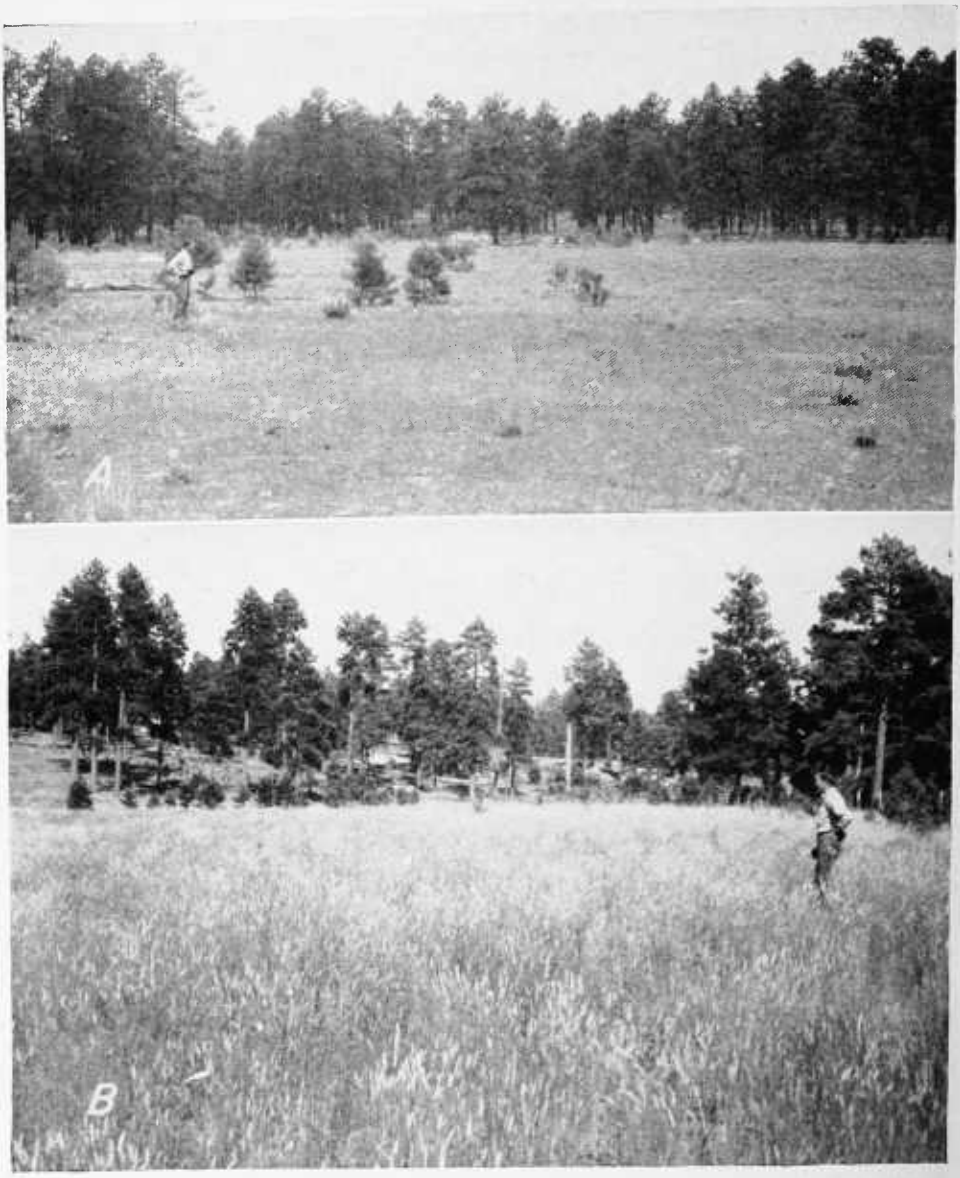

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FIGURE 2.—*A*, This deteriorated natural grassland opening in ponderosa pine range (northern N. Mex.) produced only 50 pounds of air-dry herbage per acre. *B*, An adjacent 2-year-old stand of crested wheatgrass produced 1,860 pounds per acre.

The increased forage production obtained from seeding relatively small, strategic areas can encourage improvement on adjacent areas by reducing their grazing load. Artificial seeding offers the additional advantage of providing a better seasonal distribution of forage. Species can be used that start growth earlier in the spring, or stay green later in the fall, than native summer grasses. One of the major grazing problems in northern New Mexico is the need for early spring forage. Seeded stands of crested wheatgrass are beginning to be used to relieve this shortage. Not only does this help to balance the forage supplies, but it also provides a means for deferring grazing on the high

mountain ranges where too early grazing has been the cause of much depletion in the past (fig. 3).

The green forage made available by seeding provides a more nutritious diet than do most of the native species when they are in a dormant, dry condition (*10*). This advantage is especially valuable during calving and lambing when a high level of nutrition is needed (*23, 24*). Moreover, the need for expensive supplemental feed is decreased (*27*), and it is often possible to ship grass-fat livestock direct from range to slaughter.

Severe gully and sheet erosion are common in the deteriorated pine openings, even in the relatively flat meadows and parks. For most of these openings, the reestablishment of a good vegetative cover is

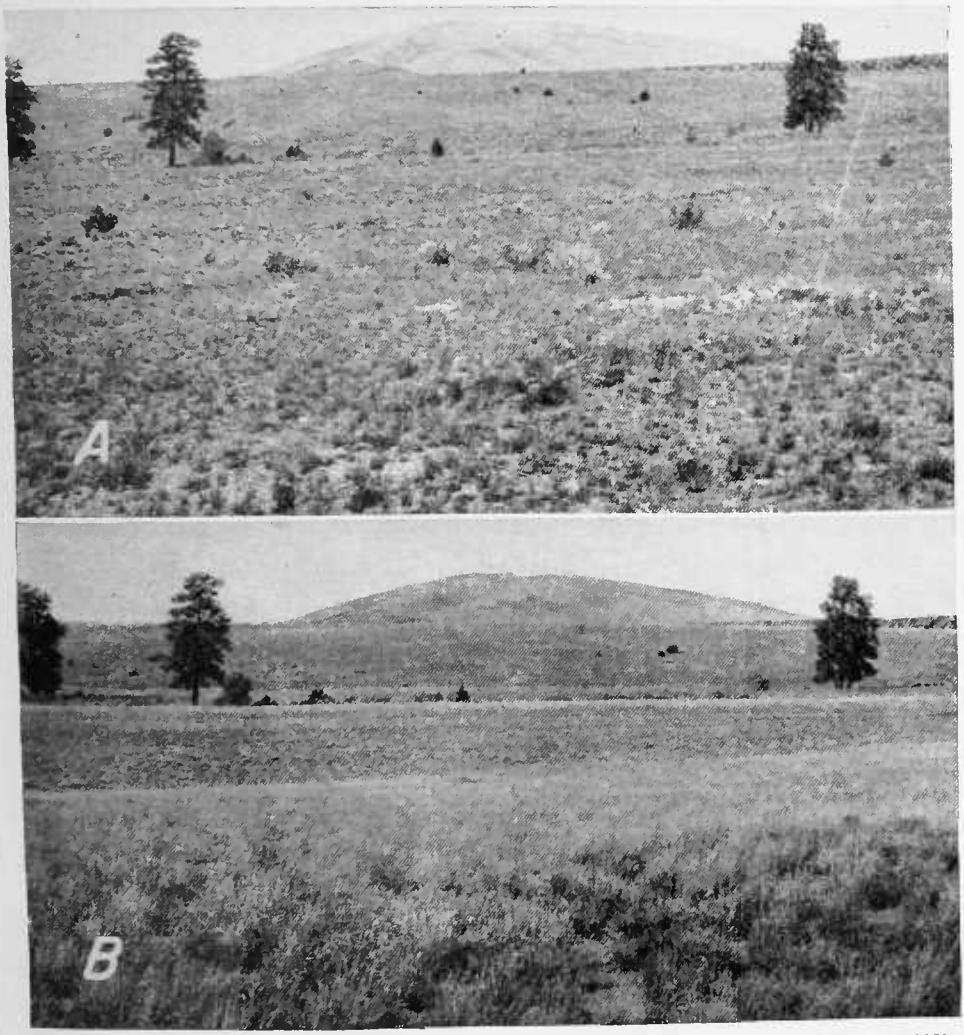

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FIGURE 3.—*A*, This deteriorated range on the Carson National Forest consisted mainly of worthless shrubs and weeds and produced less than 75 pounds of air-dry grass herbage per acre. *B*, The range is now being used to relieve early grazing pressure on higher native range. 2,200 acres, seeded to crested wheatgrass in 1949, yielded 960 pounds per acre of air-dry grass herbage at the end of the second growing season.

usually sufficient to control erosion; seeding provides a dependable and rapid method of obtaining an adequate protective cover (*4, 11, 28, 30*). However, if gullying is severe, check dams and mechanical structures for water spreading are often necessary to provide initial protection for the planting and to improve moisture conditions for plant establishment.

To Protect the Soil of Disturbed Timberlands

A need exists in the Southwest for the seeding of disturbed timberlands—that is, timberlands disturbed by fire and logging, and by the construction of roads, powerlines, pipelines, and other improvements—to reduce erosion. Wherever practical, such erosion is usually best controlled by the combined use of mechanical and vegetative means. Mechanical control is largely based on the effective drainage and proper dispersion of the surface runoff waters (*4, 25*). Seeding supplements this by providing a protective cover on the land and reducing the amount and effect of runoff.

Forest fires in Arizona and New Mexico burned at an average rate of more than 39,000 acres a year during the 6-year period 1946–51. Measurements on one pine burn in central Arizona showed initial soil losses from erosion of 165 tons per acre during the first summer. Natural recovery of protective vegetation and litter was slow, and 10 years after the fire erosion was still active. Based on siltation rates of catchment basins in unburned parts of the same general area, normal erosion on comparable undisturbed timberlands was estimated to be less than one-tenth of a ton of soil a year.

On part of a severe burn in northern Arizona, a protective cover of 430 pounds of air-dry herbage per acre was obtained in 10 weeks by seeding with black mustard. This cover greatly retarded erosion. On unseeded parts of the burn, the soil was nearly bare and it eroded seriously. On another burn in northern Arizona, intermediate wheatgrass produced 1,360 pounds of air-dry herbage per acre 2 years after the burn. The cover furnished by this seeded species protected the soil much better than did the 20 pounds per acre of natural weedy vegetation produced on the unseeded part. Seeded species, because of the large amounts of organic matter they produce (*17*), not only protect a site against deterioration (*30*) but may actually improve the soil for plant growth, both physically and chemically (*29*). (Fig 4.)

The development of skid trails and landings, slash cleanup by bulldozer, and other logging activities destroy much of the herbaceous and litter cover and compact the soil (*2, 13, 26*). Severe erosion often occurs on these areas unless both mechanical and vegetative protection are provided, resulting in decreased production of both timber (*32*) and forage, and damage to improvements (fig. 5). The recovery rate of a desirable natural protective cover is often so slow that the effects of disturbances persist over several decades and are sometimes cumulative between frequent loggings (*2, 18*). In the Southwest where logging is moving from the gentler, more accessible slopes to the more rugged terrain, erosion is a matter of increasing concern. Artificial seeding is rapidly being accepted as a means of decreasing erosion on areas disturbed by logging.

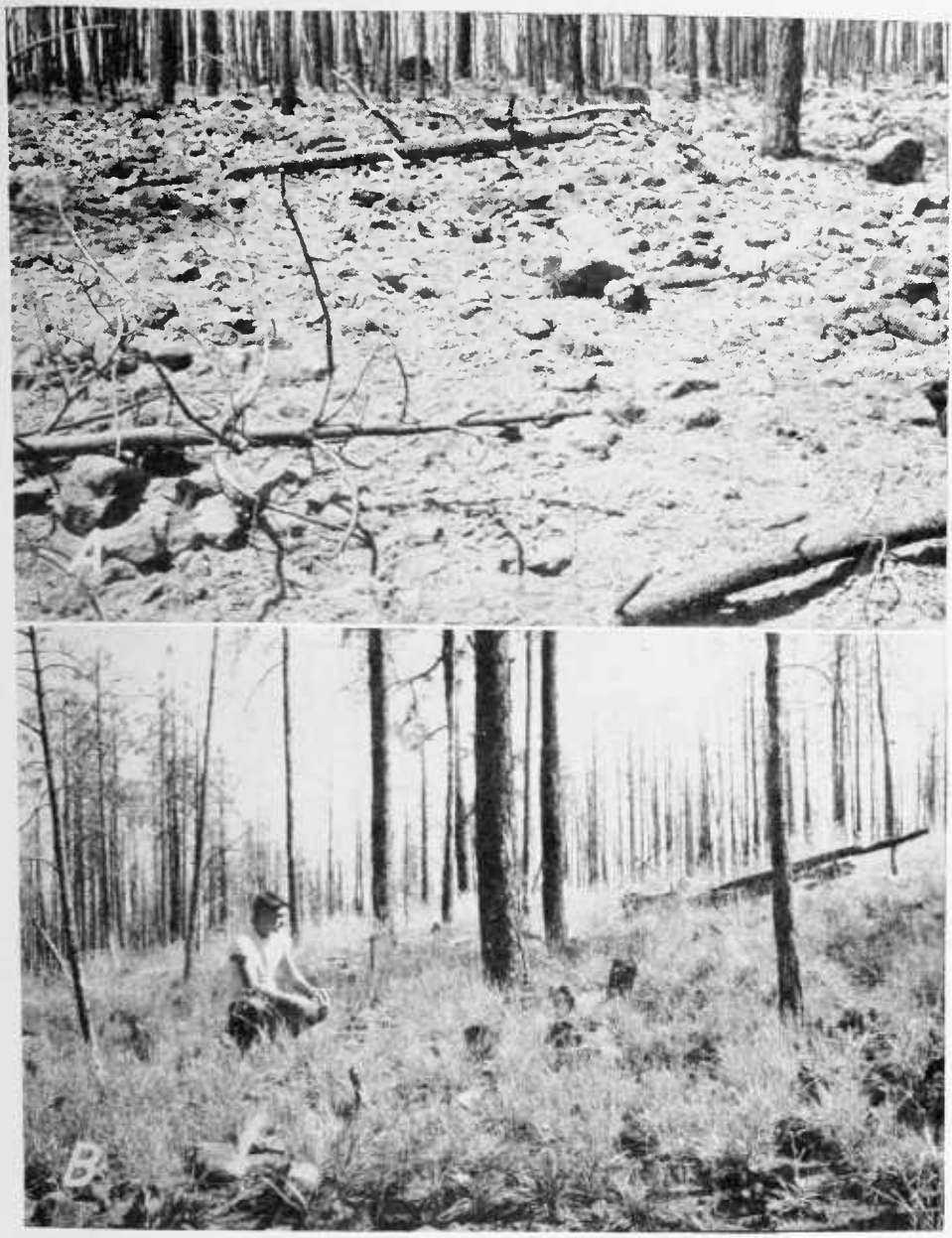

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FIGURE 4.—Artificial seeding provides a quick means of furnishing protective cover to burned over ponderosa pine timberlands. *A*, A year-old untreated burn still lacking a protective vegetative cover and subject to heavy erosion. *B*, A part of the same burn protected against erosion by seeding to blue wildrye immediately after the fire.

These logging operations often drastically decrease the available forage over large tracts of timberland (*2*, *13*, *14*). On some of these areas, seeding can be used to increase forage as an aid to better livestock management. Although artificially seeded species compete with pine reproduction for water, light, and nutrients, they probably offer no greater obstacle to pine regeneration than comparable amounts of

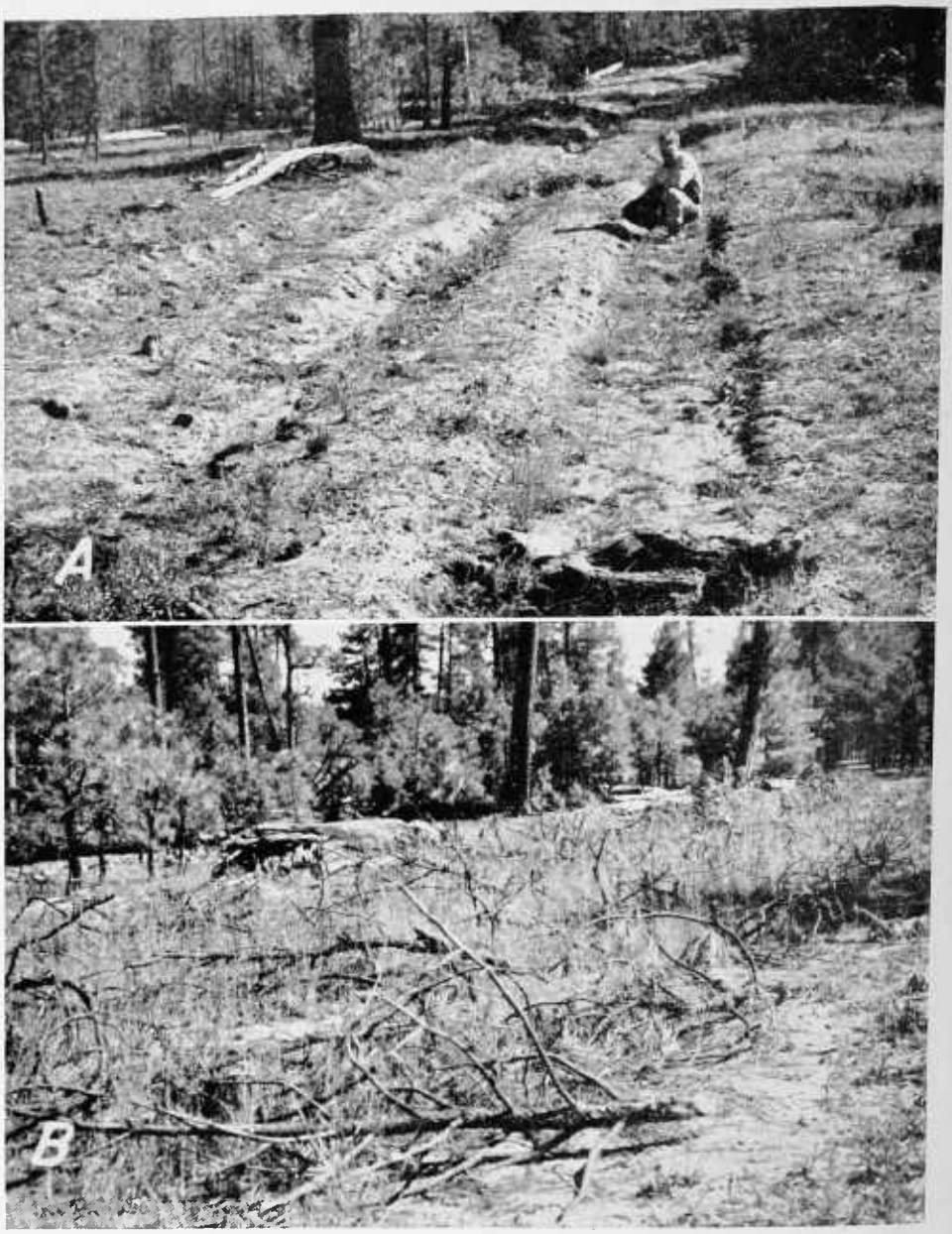

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FIGURE 5.—*A*, This untreated logging road has only a sparse stand of annual weeds 2 years after abandonment and is still subject to severe erosion. *B*, Part of same road 1 year after being seeded to big bluegrass and covered with slash; good protection against erosion has been achieved.

natural vegetation (*32*, *34*). They also have the important advantage of being easier to manipulate for silvicultural purposes through species selection, rate of seeding, and livestock grazing, than many undesirable native plants. Prompt seeding can help keep out undesirable weedy species such as bracken, pine goldenpea, and thistles. Such species frequently offer competition to pine seedlings and sometimes make reforestation difficult or impossible.

SEEDING DETERIORATED OPENINGS IN THE PONDEROSA PINE ZONE

Selecting the Site

Seeding to increase the forage supply on these natural grasslands is most useful where the vegetation consists mainly of undesirable plants or where remnants of the more desirable plants are insufficient for natural revegetation. On such ranges, soil protection against erosion is usually inadequate and forage yields are low in comparison with those on similar areas in good condition. However, where natural vegetation can be restored within a reasonable time by improved livestock-management practices alone (*13*, *36*), seeding for forage production is seldom justified. Exceptions to this sometimes occur where seeding of sites with a fair to good native vegetative cover appears justified in order to balance the green forage supply through the grazing season.

Level or gently sloping sites with fertile soil and good moisture conditions are best for planting. They should, therefore, usually receive first attention in any seeding program for forage increase and improvement. Rough terrain and shallow, rocky, or highly erosive soils are not promising sites. Generally, slopes in excess of 15 percent should not be seeded unless erosion-control benefits justify extra seeding costs.

Adapted Species

More than 170 species and varieties have been tested for use in seeding openings of the ponderosa pine zone, but only 23 have shown definite promise of being well adapted. The relative success of these species is shown in table 2.

The success rating was based on number, distribution, and vigor of plants that became established within the physical limits of the site environment. Where a full stand of well distributed, vigorous plants became established the rating was excellent. Poorer stands rated down through good, fair, poor, and very poor to complete failure. It should be noted that relative success is not always directly related to yield. For example, a low-growing species, such as blue grama, with an excellent stand might produce less herbage than a fair stand of a tall-growing species, such as tall wheatgrass.

Species used in seeding must not only be well adapted to the environment in which they are expected to grow, but they must also be suited to the purpose for which they are needed. The species listed in table 2 provide ample choice in meeting these requirements in the southwestern ponderosa pine zone. Some of their more important characteristics are therefore described. The two species that have given the most uniformly good results and that have shown the widest range of adaptability are crested wheatgrass and intermediate wheatgrass.

Crested wheatgrass, a vigorous, drought-resistant, perennial bunchgrass, produces a good amount of forage. Seedlings are small and make slow initial growth so that occasionally the first year's results do not appear successful. Usually, a good stand develops in the second or third year after seeding. One of the most valuable characteristics of crested wheatgrass is its ability to start growth early in the spring

TABLE 2.—*Relative success ratings of 23 species tested at 5 locations in ponderosa pine openings*

Species [1]	Relative success [2]				
	Jarita Mesa	Fort Valley	White Horse Lake	Peterson Flat	No Agua
Long-lived grasses:					
Bluegrass, big	E	G	F	O	NT
Brome, smooth	G	G	G	P	NT
Orchardgrass	F	F	G	O	NT
Wheatgrass:					
Beardless	G	G	F	F	F
Bluebunch	E	G	O	VP	NT
Western	F	E	E	G	NT
Crested	G	E	G	G	E
Intermediate	E	E	E	F	E
Pubescent	E	G	G	P	G
Tall	G	G	G	F	F
Wildrye, Russian	G	E	G	F	NT
Short-lived grasses:					
Brome, mountain	G	G	G	F	NT
Oatgrass, tall	G	G	G	F	NT
Rye:					
Mountain	E	E	G	G	NT
Winter [3]	G	G	E	F	NT
Timothy	F	P	F	O	NT
Wheatgrass, slender	E	E	E	G	E
Wildrye:					
Blue	E	G	F	VP	NT
Canada	F	E	F	VP	NT
Legumes:					
Alfalfa:					
Grimm	F	F	G	P	NT
Ladak	F	F	G	F	NT
Sweetclover (biennial):					
White	E	P	G	F	NT
Yellow	G	P	F	F	NT

[1] Stands ranged from 3 to 8 years in age.

[2] Relative success: E=Excellent; G=Good; F=Fair; P=Poor; VP=Very poor; O=Failure; NT=Not tested.

[3] Michel's hybrid variety of winter rye was used in all tests.

when green forage is most needed to supplement native range. In the Southwest, it often stays green and grows throughout the summer rainy season. It also makes further growth during the fall if sufficient moisture is available.

Intermediate wheatgrass, a long-lived perennial sod-former, is easy to establish because of its excellent seedling vigor and rapid growth. It produces a large volume of forage under favorable conditions and is also valuable for green feed during the spring and fall periods. This grass, however, is not so drought-resistant as crested wheatgrass. Intermediate wheatgrass does not spread so rapidly by vegetative means as some of the other sod-formers, such as smooth

brome and western wheatgrass. Established stands often become sodbound after several years with a marked decline in production of both seed and forage.

Big bluegrass, a bunchgrass, is outstanding for its high herbage yields under favorable moisture conditions. Establishment, however, is rather slow and uncertain. The young plants need careful management because they are easily pulled up and destroyed by grazing. Big bluegrass is best suited to the more moist sites.

Smooth brome, a long-lived sod-former, is easily established because it has good seedling vigor. It produces large amounts of high-quality forage where well adapted, but requires good moisture conditions and fertile soils. It is not recommended for the drier sites. Smooth brome, because of its vigorous vegetative spread, has a tendency to become sodbound in a few years time.

Orchardgrass, a bunchgrass, germinates readily and produces strong seedlings. It is shade-tolerant and maintains a good stand even under a fairly dense pine canopy. Seedlings and young plants frequently are killed during cold, open winters. In the Southwest, orchardgrass appears to require somewhat more moisture than does smooth brome and should only be planted on sites where moisture conditions are very favorable.

Beardless wheatgrass and **bluebunch wheatgrass** are closely related bunchgrasses. In the Southwest, bluebunch wheatgrass is less drought-resistant than beardless wheatgrass. These two species have not been used much in this region because of their undependable establishment and slow initial growth.

Western wheatgrass is a native sod-former. Top growth is of single stems from vigorous underground rhizomes. This plant is very drought-resistant. When top growth is killed back by drought, the underground stems may still survive. Western wheatgrass is especially well suited to heavy soils where runoff water accumulates. It starts growth early in the spring and makes further growth during the summer rainy season and in the fall. The main disadvantage of this grass for seeding is its slow, undependable germination and establishment. This is offset somewhat by its subsequent vigorous vegetative spread.

Pubescent wheatgrass is similar to intermediate wheatgrass in growth habits and requirements except that it is a more vigorous sod-former. It has a weaker seedling and is more difficult to establish than intermediate wheatgrass. Some deterioration in established 5- and 6-year-old stands of pubescent wheatgrass indicates that it may be rather short-lived under Southwestern conditions.

Tall wheatgrass is a robust, high-yielding bunchgrass and one of the latest maturing of the wheatgrasses. It has a strong, rapidly growing seedling and is easily established. During cold, open winters, mortality has been high even among mature plants. Tall wheatgrass requires better moisture conditions than either crested or intermediate wheatgrass and should therefore be used only in the moister parts of the ponderosa pine zone.

Russian wildrye is a deep-rooted perennial bunchgrass with an abundance of basal leaves. It begins growth early in the spring and usually remains green throughout the summer. Fall regrowth

is also good when adequate moisture is available. The seedling is rather weak and the young plant develops slowly. Once established, however, Russian wildrye is vigorous, persistent, and highly drought-resistant.

Reed canarygrass and **redtop**, two long-lived sod-forming grasses not listed in table 2, are mainly suited to sites that have a high water table or prolonged periods of flooding. The mature plants can endure short periods of drought. Reed canarygrass has given especially good results in reducing wave-action erosion when planted on the borders of livestock water ponds and other bodies of standing water. Redtop planted in a gully brought about a gradual rise in the water table by decreasing runoff velocity, which resulted in more silt deposition. This in turn greatly improved the forage quality and production on a former wet meadow (fig. 6). These grasses, particularly reed canarygrass, are rather slow to become established because of low seedling vigor. Once established, however, they spread vigorously by rhizomes.

Winter rye, mountain rye, and **slender wheatgrass** are widely adapted desirable bunchgrasses that have a short life span. The winter rye tested was of the Michel's hybrid variety. In the Southwest this has usually maintained a good stand over two growing seasons and then quickly declined, dying out completely by the third or fourth year. Mountain rye appears to be slightly longer lived, commonly maintaining a good stand over three growing seasons and then dying out rapidly. Slender wheatgrass is the longest lived species of this group, usually maintaining a good stand over 4 or 5 growing seasons and then deteriorating gradually. On the sites tested, good amounts of viable seed were produced by all of these species but stand propagation by volunteer seeding was very poor. The chief value of seeding with these grasses is to fill the need for a quick temporary cover. They all produce large amounts of forage that is readily grazed by livestock. Also, they are easily established because of their large viable seed, strong vigorous seedlings, and rapid initial growth.

Mountain brome, tall oatgrass, timothy, blue wildrye, and **Canada wildrye** are other desirable short-lived grasses. These usually attain maximum growth by the second to fifth year, depending on the species, then gradually decline and die out. These grasses have the same desirable seed and growth characteristics described for the preceding group of short-lived species. They are, however, less drought-resistant so that their use is limited to the more moist sites.

Grimm and **Ladak alfalfa.** Legumes are desirable for their nitrogen-fixing activity in the soil and for raising the protein level of the forage. Attempts to establish legumes by artificial seeding, however, have not been encouraging. Of the long-lived legumes, Grimm and Ladak alfalfa have shown the most promise for seeding throughout the pine zone. They are, however, highly relished by deer, rabbits, and other wildlife. Hence, grazing injury to the plants in the seedling stage is usually so great that establishment is difficult.

Yellow sweetclover and **white sweetclover,** of the short-lived legumes tested, show the greatest promise for seeding use. They are usually easy to establish and often produce a high yield of herbage.

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FIGURE 6.—*A*, A deep gully in a former wet meadow before seeding in 1946. *B*, Same gully in 1948; redtop provided a highly effective vegetative cover for soil stabilization and promoted rapid healing of the gully.

Both of these species, however, are biennials and volunteer seeding even on the better sites usually has not been adequate to maintain a good stand for a prolonged time.

HERBAGE PRODUCTION OF SEEDED STANDS

The time required to bring a deteriorated range back to good forage production by seeding may vary widely. Results indicate that the more favorable the growth conditions, especially with regard to the amount of moisture available, the more rapidly range improvement

and high forage production can be attained. For example, at White Horse Lake a stand of crested wheatgrass planted in 1946 produced 570 pounds of air-dry herbage per acre at the end of the second growing season under fair moisture conditions. At the same site a 1949 planting, after two growing seasons with poor moisture, produced only 240 pounds. At Jarita Mesa, where there were two growing seasons with exceptionally good moisture conditions, crested wheatgrass yielded 1,680 pounds of air-dry herbage per acre in the second season.

Species differ greatly in their ability to produce high herbage yields under the same growing conditions. At Jarita Mesa (table 3), for example, the 3-year average yield for big bluegrass was almost 1½ times as much as that of the next highest species, crested wheatgrass, and more than 3½ times as much as for the lowest yielding species, Kentucky bluegrass. Of the long-lived perennials tested at other locations, intermediate wheatgrass, tall wheatgrass, smooth brome, and crested wheatgrass produced the highest yields, in the order named, for the moist sites. On the drier sites, intermediate and crested wheatgrass were best. These two species, widely used in seeding throughout the pine zone, have given consistently good yields.

Yearly variations in growing conditions cause considerable variation in herbage production among artificially seeded species. Reynolds and Springfield (*36*) found in the Southwest that yields of crested wheatgrass were closely correlated with the amount of precipitation received from November to June. Because this species makes its best growth during the cool spring weather, good moisture is needed at that time for maximum herbage production. Studies indicate that other cool-weather grasses are also dependent on good winter-spring moisture for high herbage yields. For example, figure 7 shows that herbage yields of intermediate wheatgrass, crested wheatgrass, and smooth brome were all more closely related to November-June precipitation than to total annual precipitation.

Caution should be used in projecting herbage yields for young, artificially seeded stands and in comparing them with native range; there are indications that these young stands may reach an early peak yield and then decline even under light grazing or complete protection. This has been true in other regions of the West. In the southwestern ponderosa pine zone, a decrease in herbage yields has been observed for some of the stands seeded at the beginning of the 1945 research program. However, definite conclusions cannot be drawn from these observations because of the limited period of record and the influence of a severe drought.

In northern Arizona, one pasture of smooth brome that was seeded more than 30 years ago is still highly valued by the owner for the green spring feed it furnishes for his sheep. Herbage yields, however, are much lower than for adjacent native range in good condition. This is probably the result of sodbinding and a nitrogen deficiency in the smooth brome stand. Several stands of crested wheatgrass in both northern Arizona and northern New Mexico that have been grazed for 15 to 20 years still equal or exceed good native range in forage yields.

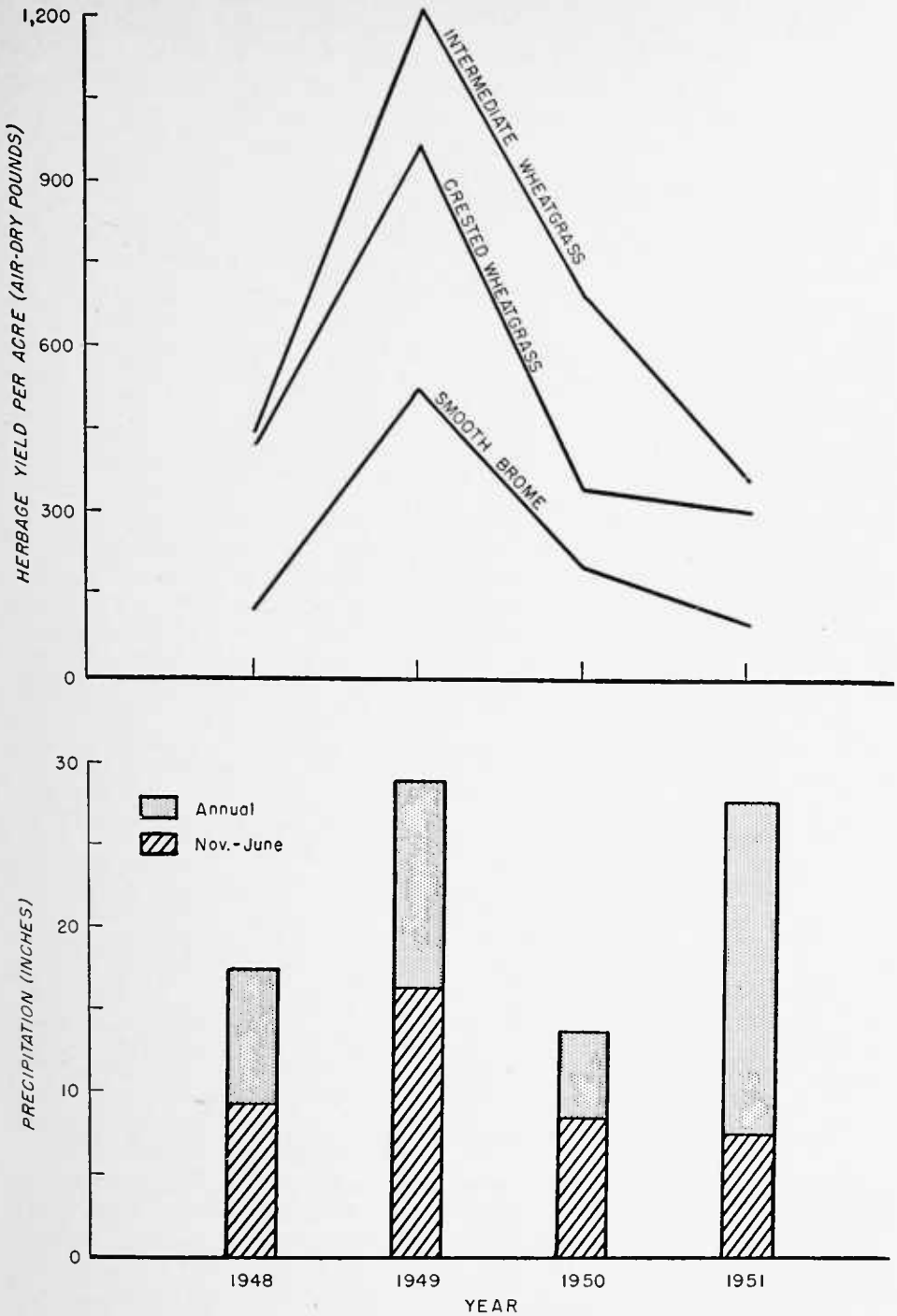

FIGURE 7.—Comparative yearly fluctuations of precipitation and herbage production of 3 species seeded in 1947 on a dry slope, Fort Valley Experimental Forest, Ariz., 1948–51.

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TABLE 3.—*Herbage yields over a 3-year period for 8 species seeded in 1946 at Jarita Mesa, northern New Mexico* [1]

Species	Herbage production, in air-dry weight per acre			
	1947	1948	1949	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*
Big bluegrass	1, 370	2, 610	2, 050	2, 010
Crested wheatgrass	1, 680	1, 480	1, 140	1, 430
Slender wheatgrass	1, 060	1, 220	1, 070	1, 120
Western wheatgrass	610	750	1, 000	790
Smooth brome	560	760	620	650
Orchardgrass	680	830	420	640
Tall oatgrass	640	650	430	570
Kentucky bluegrass	570	490	610	560

[1] Annual precipitation in 1947, 28.0 inches; 1948, 26.4 inches; 1949, 20.3 inches.

Mixtures of species for range seeding have been tested for such a short time that only preliminary indications of their potentialities are available. At the end of the third growing season none of 15 perennial grass mixtures tested at White Horse Lake produced a greater yield of herbage than the best single-species planting. This agrees with results obtained in southern Idaho (*40*) and appears to substantiate Willard's conclusions (*46, pp. 431–447*) that where one species is best adapted to a site for high forage production, any mixture of less well adapted species is likely to reduce the yield.

On improved pastures where legumes are adapted, legume-grass mixtures may improve forage quality and increase production over grasses alone (*46*). The only test of this on rangelands in the pine zone was at Jarita Mesa. There a mixture of Ladak alfalfa, crested wheatgrass, orchardgrass, and smooth brome, and another of Grimm alfalfa, crested wheatgrass, and slender wheatgrass, gave good preliminary results. These mixtures outyielded the same grasses seeded in pure stands. However, big bluegrass, the highest producing single species, outyielded both of the mixtures.

Balancing Seasonal Forage Needs and Improving Forage

Seasonal forage needs can be balanced and the nutritional value of the forage improved by lengthening the time during which green feed is available. To accomplish this, species must be seeded that have growing periods that will supplement each other as well as the growth of the native range (*17, 40, 45*). For example, crested wheatgrass starts growth very early in the year and provides good, early spring grazing. Intermediate wheatgrass, however, stays green longer and is more suitable for late spring and early summer grazing. With summer rains, the native range species start growth and furnish green forage throughout the summer months. Russian wildrye, which usually makes excellent fall regrowth, is well adapted for fall grazing. The combined use of these three species together with the native range

could therefore provide a constant supply of green forage from early spring till late fall.

Green range forage as compared with naturally cured range forage contains larger amounts of some of the most important required nutrients, particularly protein, phosphorus, and vitamin A (*10*, *37*). Thus, lengthening the period of green feed also improves the nutritional level.

Table 4 gives the seasonal value of the more important species used in seeding for green forage production. This table is based on observation over an 8-year period and supplemented by the results of other investigators (*12*, *44*).

TABLE 4.—*Seasonal value* [1] *of the more important species used in seeding for the production of green forage in the Southwest*

Species	Early spring grazing	Late spring and summer grazing	Fall grazing
Big bluegrass	G	F	P
Crested wheatgrass	G	F	F
Russian wildrye	G	F	G
Intermediate wheatgrass	F	G	G
Pubescent wheatgrass	F	G	F
Orchardgrass	F	G	G
Smooth brome	F	G	G
Western wheatgrass	F	G	F
Beardless wheatgrass	F	G	P
Bluebunch wheatgrass	F	G	P
Tall wheatgrass	P	G	G

[1] Seasonal value: G=Good; F=Fair; P=Poor.

When range seeding is done to increase the length of the grazing season, species are best planted singly in separate pastures and grazed in rotation. This provides forage when needed, and management is easier than for pastures planted to mixtures (*16*, *45*). Mixtures in which the component species vary widely in palatability and season of use are difficult if not impossible to manage efficiently. An example of this occurred near Flagstaff, Ariz., where a mixture of smooth brome and crested wheatgrass was used. Because the smooth brome was far more palatable to the livestock, it was grazed, and the crested wheatgrass was left to mature and become even less palatable. In 4 years, the smooth brome was almost eliminated by overgrazing.

Grazing Preference

Grazing preference, or palatability, should be considered when selecting species for seeding to meet grazing needs. Limited grazing trials that allowed livestock free choice of species artificially seeded were made at Jarita Mesa and the Fort Valley Experimental Forest. Although these trials included only a few species tested for fall graz-

ing, they illustrate the difference in utilization that can be expecte when species that vary in palatability are grazed together.

At Jarita Mesa (*39*), cattle were allowed free-choice grazing of seeded grasses over a 23-day period from August 21 to September 12 During the first week no one species made up more than 26 percen of their diet, yet certain species were clearly preferred. As thes became scarce, a progressively greater proportion of the others were consumed (fig. 8). Cattle showed the greatest preference for grasse that were most succulent during the grazing period: orchardgrass

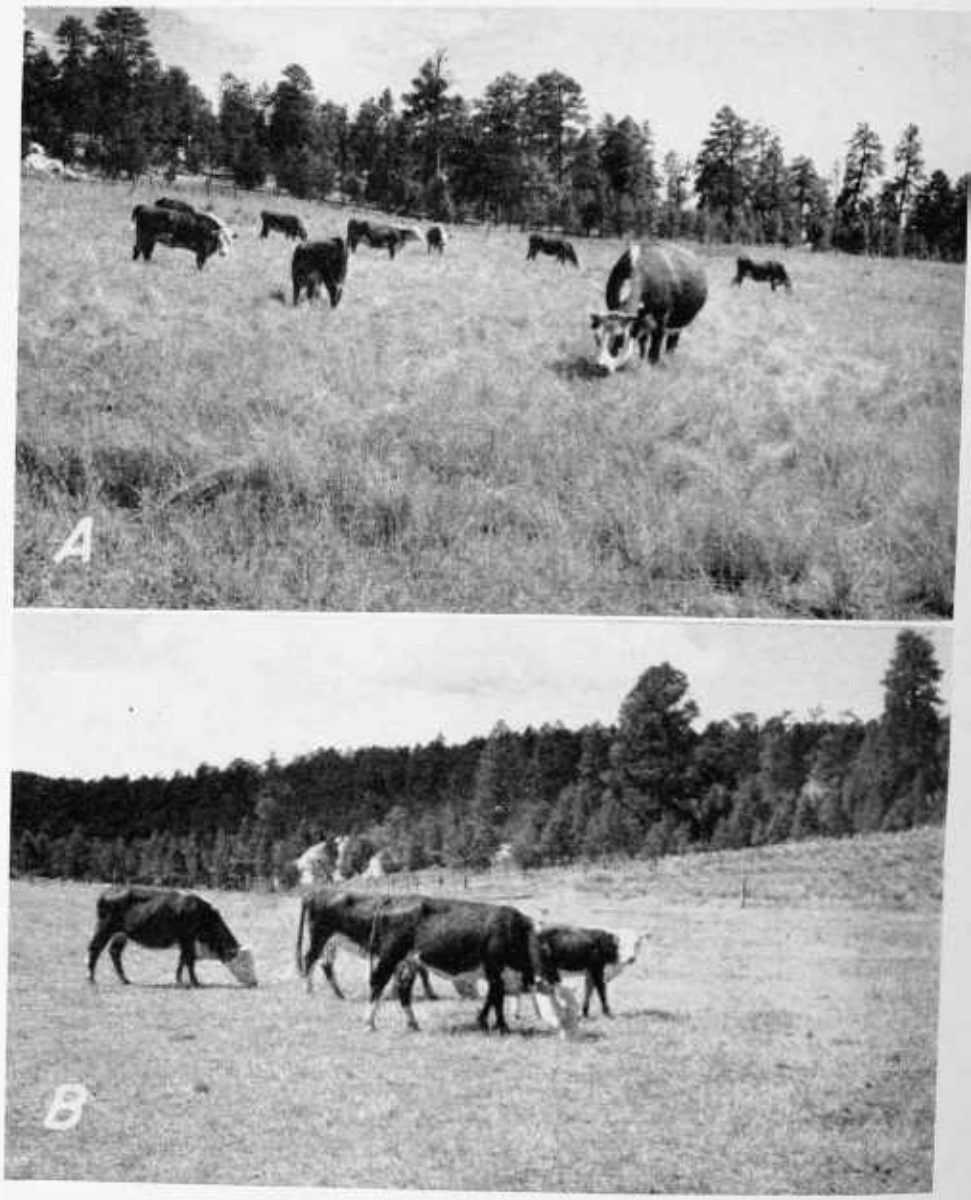

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FIGURE 8.—These two plots in the same field were subjected to free-choice fall grazing. *A*, Big bluegrass, a species of low palatability in the fall, was only lightly used. *B*, Smooth brome, a highly preferred fall species was heavily used.

smooth brome, and slender wheatgrass. Crested wheatgrass, tall oatgrass, and Kentucky bluegrass were considerably less palatable, and big bluegrass and western wheatgrass were grazed the least. At the Fort Valley Experimental Forest, smooth brome—the most succulent grass—was preferred to crested and intermediate wheatgrasses by sheep grazing during a September 20 to October 10 grazing period.

These results suggest that grasses that stay green and succulent well into late summer and fall provide preferred forage during that period and may be particularly useful for late-season grazing. Also, they further illustrate the need for considering the relative palatability of the component species in mixtures. Unless plants of similar preference are used together, selective grazing may eventually eliminate the highly preferred species.

On large plantings, cattle distribution might be improved by planting highly preferred species on areas that generally receive light use and the less preferred on heavily used areas, such as those near water (*22*, *39*).

Guides For Establishing Successful Seeded Stands

Successful range seeding depends upon the use of good planting methods. The main considerations are (1) site preparation; (2) seed distribution and coverage; (3) seeding rates; and (4) time of planting. Special consideration for all of these often makes the difference between success and failure.

Site Preparation

Removal of the competitive native cover before seeding is essential for good results. Plants of seeded species have a difficult time becoming established, and they often die if most of the soil moisture is being used by the low-quality native vegetation of the deteriorated site. Reynolds and Springfield (*36*), for example, found that the greater the amount of competition removed the better the establishment of the seeded stand.

On heavy or compacted soils in poor physical condition, shallow cultivation to a depth of 3 or 4 inches improves the structure of the surface soil (*3*, *29*). This, in turn, favors seeding success by improving the water absorption and aeration conditions necessary for good plant growth. Deep cultivation under range conditions usually gives no particular advantage over shallow cultivation. Actually, it is sometimes detrimental where seeding has to be done soon after cultivation, because it creates an excessively loose seedbed; or the more fertile topsoil may be covered by raw, unproductive subsoil (*3*, *36*).

Disk-type plows (fig. 9, *A*) and extra-heavy-duty offset disk harrows with weights of 500 pounds or more per foot of cutting width (fig. 9, *B*) have generally proved best for preparing sites. They are superior to moldboard plows and other similar types of equipment, because they can be operated more economically, with less power, in rockier ground, and under a wider range of soil conditions.

Disk plowing has generally produced the best site preparation, as indicated by seeding results. At White Horse Lake, for example, turning the heavy clay soil to a depth of 3 or 4 inches with a standard disk

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FIGURE 9.—*A*, The brushland plow, recently developed by the U. S. Forest Service, has proved very effective for site preparation under a wide variety of conditions. Paired disks, held in the ground under spring tension, rise over stumps or rocks, thus reducing breakage. Cost of site preparation is greatly reduced by pulling two of these plows in tandem. *B*, The extra-heavy-duty offset disk is well suited for preparing sites where soil are heavy and relatively rock-free. Here it is being used to remove low-value plants from a deteriorated pine opening.

plow destroyed the competing vegetation and left the soil in a satisfactory condition for planting. An average of 0.7 crested wheatgrass plant per square foot was established, enough for a full stand. Once over with a light offset disk gave poorer site preparation, and only

0.1 plant per square foot was established, an inadequate stand. Pitting disturbed only a small part of the ground surface and removed too little of the competing vegetation; only an occasional plant of crested wheatgrass became established. Planting without site preparation resulted in almost complete failure. All seeding was done with drills.

Firming the soil by disk harrowing or cultipacking improves stand establishment in regions other than the ponderosa pine zone, especially where the seed is planted with a single-disk grain drill on loose soils (*21, 46, pp. 431–447*). In the Southwest, however, the use of these methods after initial shallow plowing has not improved stand establishment. The smoother soil surface resulting from disk harrowing or cultipacking is generally not desirable wherever wind and water erosion is likely to be serious.

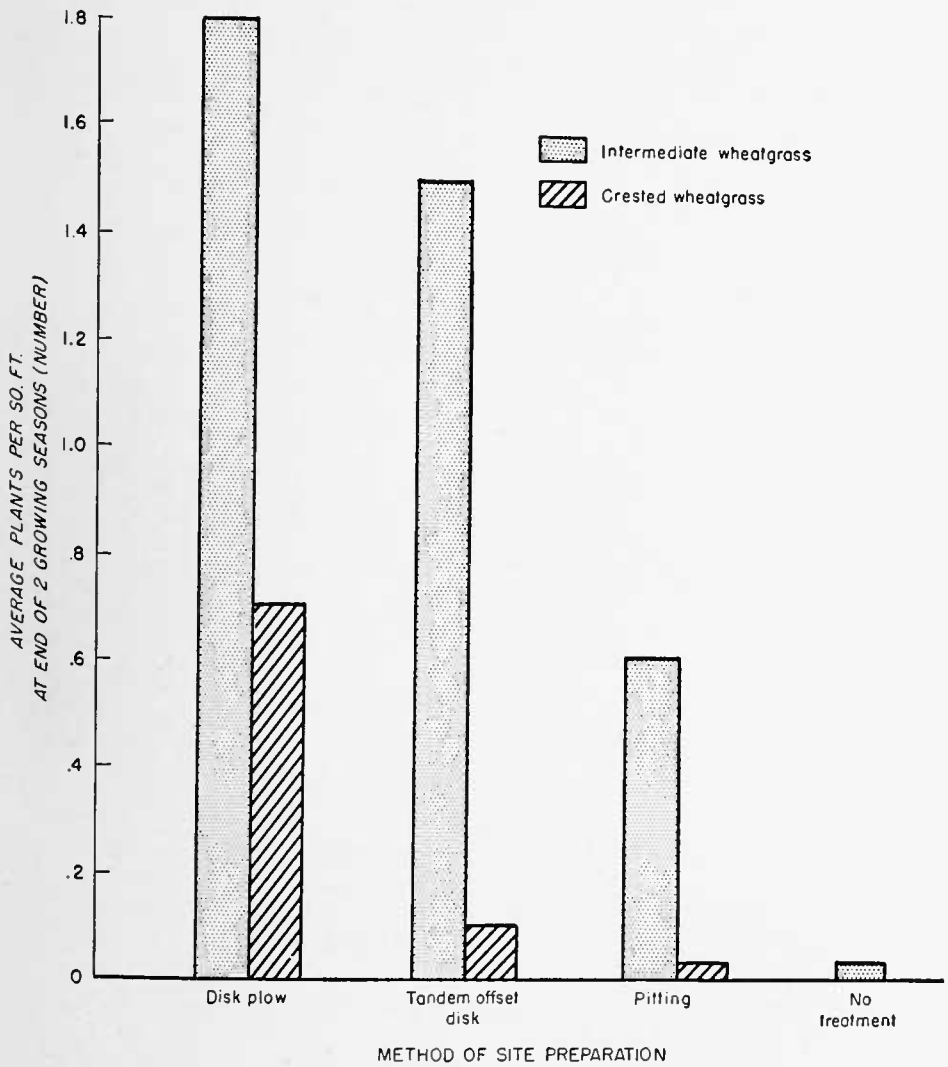

FIGURE 10.—Effects of different methods of site preparation upon the establishment of crested and intermediate wheatgrass at White Horse Lake, Ariz.

High standards for site preparation should always be observed. However, there are indications that cultural requirements may vary somewhat with seedling vigor of the species used (*40*). At White Horse Lake, for example, intermediate wheatgrass with its large, vigorously germinating seed and strong seedling became well established when planted after the site was prepared by either a disk plow or a lighter tandem disk. Crested wheatgrass, which has a relatively weak seedling, became well established only when planted on the better prepared site, obtained with a disk plow (fig. 10).

Effects of different intensities of site preparation may persist over a number of years. At White Horse Lake, crested wheatgrass planted after disk plowing initially outyielded stands planted where less intensive methods were used. At the end of 4 growing seasons, plantings on the plowed areas were still best, yielding almost 3 times as much as plantings on areas prepared with a light tandem disk, and more than 4 times as much as those on pitted areas (fig. 11). Differences between the plowing and disking seemed to be mainly the result of the depth of cultivation, since nearly all of the native plant com-

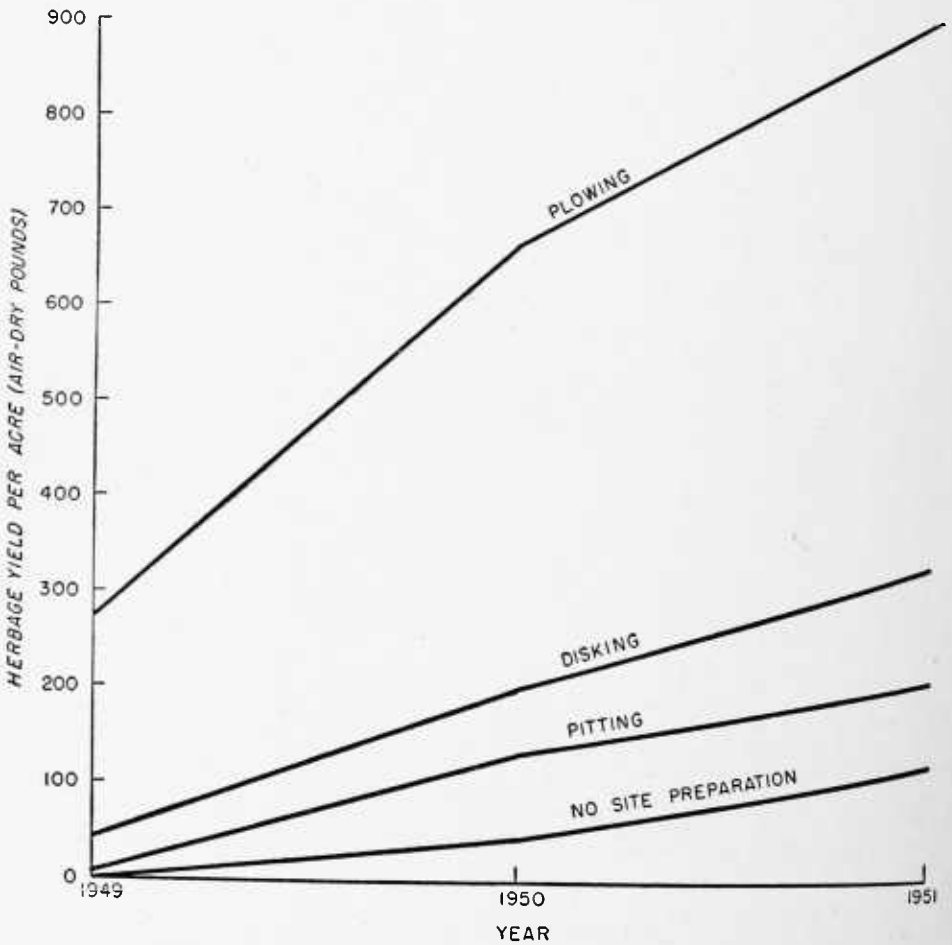

FIGURE 11.—Residual effects of different site-preparation methods on the production of crested wheatgrass planted in 1948 at White Horse Lake, Ariz.

petition had been eliminated. For pitting and where there was no site preparation, however, the competing native vegetation had not been adequately removed and plant establishment for the seeded stand was poor. The more intensive site-preparation method may thus more than pay for itself not only in more certain establishment, but in increased forage yields over several years.

Seed Distribution and Coverage

The main requirements of a good planting method are uniform seed distribution together with good control of rate and depth of seeding. Drilling most nearly fulfills these requirements. Broadcasting is useful where drilling is not feasible because of rough, rocky, or trashy ground or inaccessibility.

Covering the seed helps to protect it against loss from drying, excessive heat, and rodents and insects. Care must be exercised, however, to prevent covering the seed so deeply that the seedlings are unable to emerge. Optimum planting depth for most of the species adapted to pine openings is ½ to 1 inch (*7, 12, 20, 37*). Exceptions are the smaller seeded species, such as orchardgrass, big bluegrass, timothy, the alfalfas and sweetclovers. The best depth for these is ¼ to ½ inch. Seed should be planted slightly deeper on light sandy soils and shallower on heavy clay soils or soils that crust readily.

Although drilling is usually the most dependable seeding method (*21, 36*), broadcasting on a loose, well-prepared seedbed will often give as good results. This is illustrated in the following data for a plowed seedbed at White Horse Lake where favorable rainfall occurred soon after planting.

COMPARATIVE YIELDS FROM 3-YEAR-OLD CRESTED WHEATGRASS

Seedbed preparation and planting method [1]	*Air-dry herbage yield per acre (pounds)*
Disk plow:	
Drill	645
Broadcast	680
Disk:	
Drill	265
Broadcast	130
No preparation:	
Drill	60
Broadcast	25

[1] All broadcast seeding made without mechanical seed coverage.

On the poor seedbeds, however, the benefits of drilling are more marked. Here the drilled areas produced more than twice as much as the broadcast. These results also indicate that drilling cannot entirely compensate for poor seedbed preparation.

The single-disk grain drill has given good results on trashy or hard seedbeds. To minimize breakage, it should not be used on excessively rocky or trashy sites or on steep slopes and should be operated at speeds of only 2 to 3 miles per hour. On loose seedbeds where there is danger of the seed being planted too deeply, depth regulator bands on the disks can be used. Seed broadcast on a loose soil surface is usually adequately covered by natural sloughing and settling. Where the ground has not been well loosened by cultivation during the preparation of

the site, or where it has become compacted again, mechanical coverage is necessary.

Rotary-type hand seeders are well suited for broadcasting small areas. Where greater acreages are involved, the use of larger mechanical broadcasters of either the seedbox or rotary type is more efficient. When seed coverage after broadcasting is necessary, it can be done satisfactorily with light harrows or disks, or with drags constructed of brush, rails, or chain.

Rate of Seeding

Optimum rate of seeding varies with quality of seed, size of seed, seedling vigor, growth characteristics of the species, condition of the seedbed, and the efficiency of the seeding method (*7*, *21*, *37*). Table 5

TABLE 5.—*Standards of seed quality and recommended seeding rates for species adapted to the ponderosa pine zone*

Species	Purity [1]	Germination [1]	Seeding rate per acre [2]
	Percent	*Percent*	*Pounds*
Alfalfa:			
Grimm	98	[3] 90	8–10
Ladak	98	[3] 90	8–10
Bluegrass, big	85	72	6–10
Brome:			
Mountain	98	85	10–15
Smooth	93	88	8–12
Oatgrass, tall	85	80	10–12
Orchardgrass	85	85	6–10
Rye:			
Mountain			15–20
Winter	97	78	15–20
Sweetclover:			
White	98	[3] 90	8–10
Yellow	98	[3] 90	8–10
Timothy	97	86	4–6
Wheatgrass:			
Beardless	92	90	8–10
Bluebunch	94	90	8–10
Western	80	80	10–15
Crested	95	85	4–7
Intermediate	89	91	6–10
Pubescent	93	85	6–10
Slender	95	85	8–10
Tall	94	90	8–12
Wildrye:			
Blue	96	88	10–15
Canada	85	85	10–15
Russian	91	85	8–10

[1] When seed is used that does not meet the specified standards of purity and germination, seeding rates must be increased to compensate.

[2] The lower rates are for use under the most favorable seedbed conditions, where there is a good chance for a large percentage of the seed to develop into mature plants. The higher rates are for poorer conditions where there is the possibility that much of the seed will be lost. For seeding mixtures, reduce and adjust according to the number of species sown and the proportion desired.

[3] Medium percent hard seed.

gives the recommended standards of seed quality and seeding rates for adapted species based upon tests, experience, and other available information pertinent to the Southwest (*7*, *8*, *12*, *42*). For most of the species, these rates have been used with success on either experimental or project plantings. However, they are not all based on critical tests of comparative rates and therefore cannot be claimed to be optimum.

The use of appropriate seeding rates is important for successful and economical range seeding. Too little seed results in a sparse initial stand that requires a long waiting period before full production is achieved. Moreover, during this time the stand is always open to the danger of invasion by undesirable, weedy plants (*21*). On the other hand, too much seed increases costs without increasing benefits. It may actually be harmful where moisture is limited; competition among individual plants can be so intense that the chances of obtaining a vigorous initial stand will be lessened (*36*, *37*), and crowding often reduces herbage yields (*46*, *pp. 431–447*).

Some of these effects are illustrated by results from tests at Fort Valley, Ariz., (fig. 12). Crested wheatgrass was seeded at rates of 4,

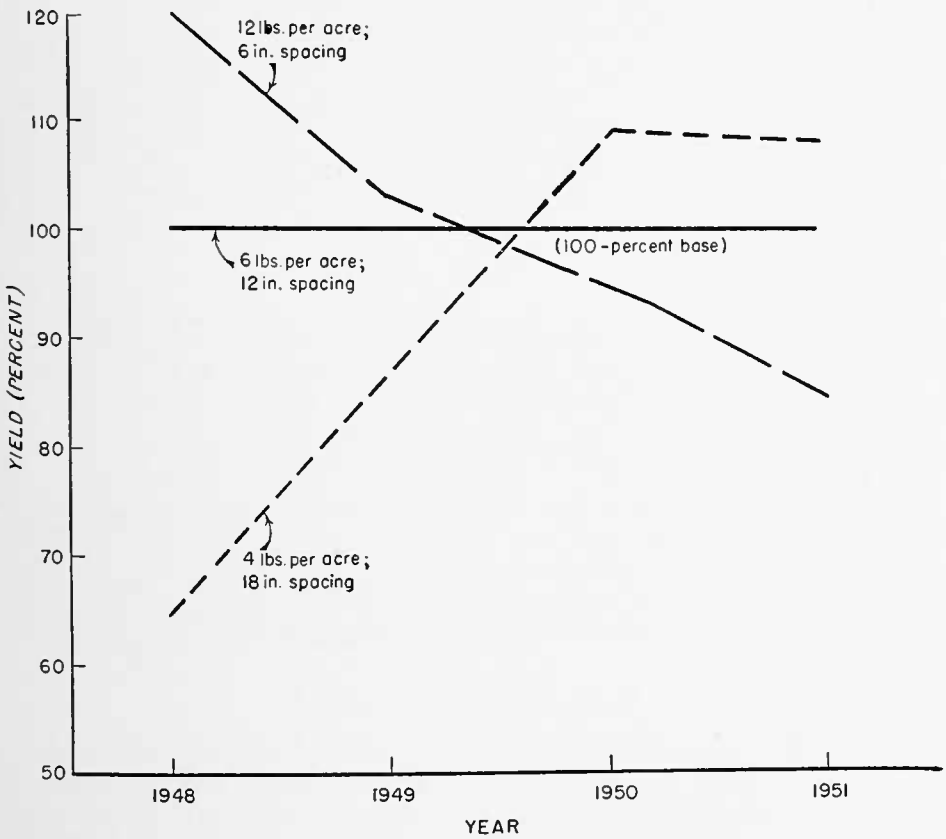

FIGURE 12.—Effect of seeding rates and drill row spacings on relative yields of crested wheatgrass stands planted in 1947 at Fort Valley Experimental Forest, Ariz. (Annual precipitation October 1 to September 30: 1948, 17.1 inches; 1949, 27.4; 1950, 19.5; 1951, 18.2.)

6, and 12 pounds per acre in drill rows spaced at 18, 12, and 6 inches, respectively, in 1947. During 1948, when the plants were still too small to fully occupy the site, and also in 1949 when moisture conditions were above average, the highest seeding rate produced greatest yields. But in 1950 and 1951, which were dry years, stands from the lowest seeding rate produced highest yields.

Drill Row Spacings

When seeding rangelands with a drill, 12-inch drill row spacings are commonly recommended. In some cases 6- or 7-inch spacings are preferred on moist sites, and spacings wider than 12 inches on the drier ones.

Tests with tall fescue in Texas indicated that plant survival could be increased by planting in rows spaced at least 14 inches or more apart. Also, yields were significantly greater in the wider drill row spacings at the same seeding rate per acre (*19*). Although tests with crested wheatgrass in Montana and Idaho showed no significant difference in herbage yields from drill row spacings ranging from 6 to 30 inches, the 6-inch spacing was preferred for protection against erosion and weed invasion, and for producing a finer, more palatable forage (*20*).

As already shown (fig. 12), 18-inch drill rows and a low rate of seeding produced highest yields of crested wheatgrass in dry years at Fort Valley, Ariz. Similar results were obtained on dry sites north of Williams, Ariz., and in northern New Mexico. At all locations, greatest size and vigor of seedlings and mature plants alike were obtained with the widest spacing (18 inches) and the lowest seeding rate (4 pounds per acre) (fig. 13). Also, the widely spaced plants stayed greener during dry periods. However, earlier yields were higher from the closer row spacings, and later the plants tended to be finer stemmed and perhaps most palatable.

At least for crested wheatgrass, the experimental evidence, together with observations of many plantings, suggests that a drill row spacing of 12 inches is generally well suited for the conditions found in the southwestern ponderosa pine zone. This spacing, together with the median seeding rates shown in table 5, has resulted in good forage production, and the ground cover obtained is apparently adequate protection against erosion and the invasion of undesirable weedy plants. Any deviation should probably be toward closer spacing and higher seeding rates for the moister sites or poor seedbeds, and wider spacing and lower seeding rates for drier sites and good seedbeds.

Best Time for Planting

Moisture is the most important single factor affecting the successful establishment of seeded stands (*7*, *20*, *36*, *41*). Temperature, although important, is much less limiting (*41*). Throughout the southwestern ponderosa pine zone the driest weather occurs during the spring months of April, May, and June, and the next driest occurs in the fall months of September and October. The largest and most dependable amounts of rainfall of the entire growing season are

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FIGURE 13.—Adjacent 3-year-old stands of crested wheatgrass at Fort Valley, Ariz. Larger plants with increased vigor resulted from wider drill row spacings and lower seeding rates. *A*, 18-inch spacing, 4 pounds of seed per acre; *B*, 12-inch spacing, 6 pounds of seed per acre; *C*, 6-inch spacing, 12 pounds of seed per acre.

usually received during the summer months of July and August. November, December, January, and February, though usually receiving good precipitation, are mainly too cold for germination and growth (*7*, *36*).

For the southwestern ponderosa pine zone as a whole, plantings made from about the middle of June to the middle of July, just prior to or at the beginning of the summer rains, have been most consistently successful. However, even plantings in this season may fail in years when rainfall is greatly below average. Later plantings do not have full advantage of all the summer precipitation, and the results are therefore less dependable. Because seedlings from early summer plantings are generally further developed, they survive winterkill, frost heave, and drought better than plantings made at other seasons (*7*, *20*, *36*).

The principal danger to spring plantings is from light, infrequent showers that may provide enough moisture for seed germination but not enough for the survival of the seedling. Plantings during this season may occasionally be successful when moisture conditions are unusually favorable or when the weather is dry enough to prevent germination until dependable summer rains begin. Spring plantings suffer more from weed competition than plantings made at other times.

Seed planted in the fall either germinates before winter begins, or it lies dormant through the winter and germinates on early spring moisture. The small size of fall seedlings makes them more susceptible to winterkilling and frost heaving than are larger plants. Mortality during the spring dry period is high for both fall and spring seedlings unless there is an abundant reserve of soil moisture from melting snow.

A dependable heavy snowfall, which usually occurs at the higher elevations, increases the possibilities for successful fall plantings. The snow blanket protects seedlings from frost heaving and other winter injury. Moreover, the melting snow provides enough additional moisture to carry the young plants through the normally dry spring season.

Figure 14 indicates how important the seasonal distribution of precipitation was for 8 grasses seeded over a 5-year period at Fort Valley, Ariz. In 1946, a year when the largest amount of rain fell in August, the July plantings excelled. In 1947, the May as well as the July plantings were good because the spring was so dry that the seed planted in May remained dormant until July. Thus, both plantings had full advantage of the summer rains. The November plantings of 1948 were unusually good because of an extremely heavy snowfall that melted slowly and kept the soil moist until late spring. The September plantings were good in 1949 owing to an unusually large amount of rainfall during September and October of that year. Both May and July plantings were best in 1950 because the May-June period was very dry and July was the only month that received favorable precipitation. For the 5-year period as a whole, the summer plantings were the only ones that consistently rated good or better.

Final judgment of seeding success should be delayed for at least two growing seasons. Sometimes germination is delayed or seedling growth is slow during the first year, but such stands frequently overcome any initial setback and are highly successful. Moreover, seedlings of some species, such as crested wheatgrass, are small and easily overlooked the first growing season.

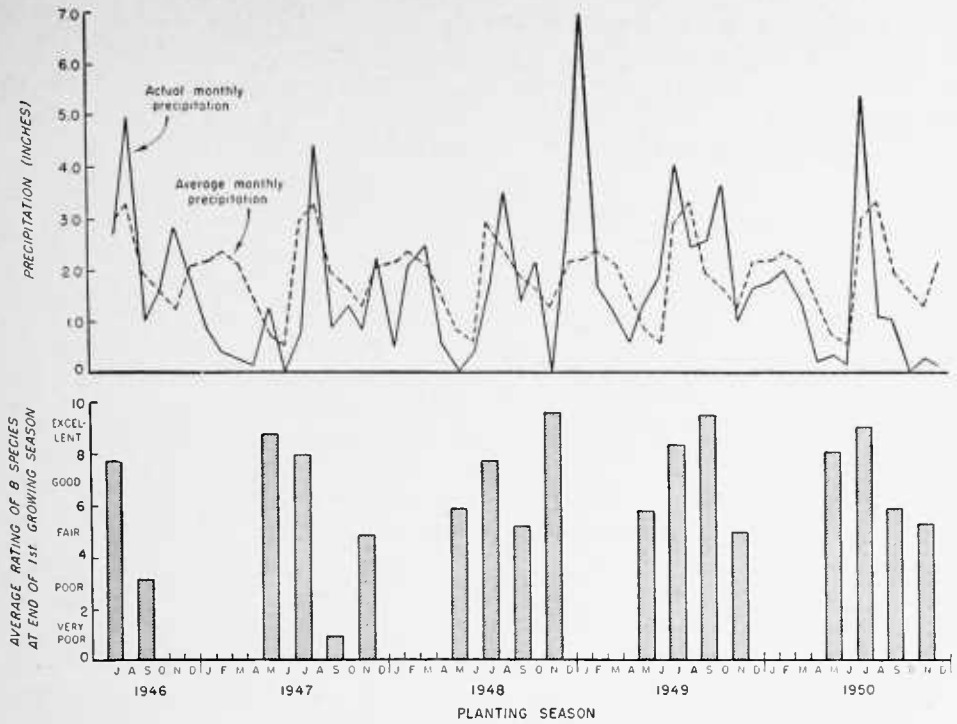

FIGURE 14.—The relation of seasonal distribution of precipitation to the success of range seeding, for stands seeded in May, July, September, and November 1946–50. (Fort Valley Experimental Forest, Ariz.)

GUIDES FOR GRAZING SEEDED STANDS

Good livestock management is essential for the establishment and maintenance of seeded stands. Seeding should be a carefully integrated part of the overall range-management plan, not a substitute for it.

For the greatest efficiency, integrated plans for grazing-management fences, water development, and other range facilities should be made before seeding. Fences can often be used for the dual purpose of protecting the initial seeded stand and for livestock control after stand establishment. More water developments and fences are usually justified by the increased forage on seeded ranges. Well-located range improvements will more than pay for themselves in benefits derived from the easier management and more efficient use of the seeded stand.

Management of New Stands

New plantings need protection for at least the first two growing seasons so that the plants can develop enough root system and top growth to withstand grazing. If seed has been produced, very light grazing at the end of the second growing season may be beneficial. For example, on the Carson National Forest in northern New Mexico light grazing of crested wheatgrass during the second year, when the seed was in the shattering stage, resulted in a thickening of the stand and the establishment of new plants in bare spots. On the part of the

stand protected from grazing, new seedlings were much less numerous. Grazing of young stands when the ground is moist and soft is especially harmful. It causes undesirable soil compaction and, in addition, the young plants are easily pulled out of the ground and destroyed by the grazing animals.

Grazing Established Stands

The most important single rule to follow in the management of established seeded stands is conservative grazing. This gives maximum benefits in maintenance of the stand, in livestock production, and in soil protection. Overuse, on the other hand, causes stand deterioration, which ultimately means lower grazing capacity. Utilization standards have not yet been developed for most of the species adapted to seeding. However, preliminary research results for crested wheatgrass (*36*), and experience from grazing large plantings, show that stands can be satisfactorily maintained when up to 50 percent of their total herbage is grazed.

The annual grazing capacity of seeded stands fluctuates widely in response to growing conditions. When moisture is plentiful, forage production is high. But drought lowers plant vigor and causes low yields (fig. 7, p. 15). To avoid jeopardizing the survival of a seeded stand, grazing management must be flexible enough to take advantage of extra forage during good years and to decrease grazing use when forage production is low during poor years. If this is not possible, the best alternative is to stock at the lower limits of forage production.

The fluctuations in grazing capacity of crested wheatgrass, based on 50-percent utilization at Fort Valley over a 4-year period, point up the danger of trying to stock a seeded stand on the basis of average grazing capacity. Acreage required per cow month: 1948, 1.82; 1949, 0.82; 1950, 2.08; 1951, 2.22; average, 1.73. Had stocking been based on the average requirement of 1.73 acres per cow month, the stand would have been overgrazed in 3 out of 4 years.

While there is admittedly some danger of error in predicting the amount of forage that will be available each year on any seeded stand, the stockman or range administrator can make reasonably satisfactory adjustments in numbers of livestock on the basis of observation and experience. Visual appraisal of the range at the time livestock are turned in, study of stocking and utilization records of previous grazing seasons, and consideration of current rainfall and weather conditions will all aid in setting the proper stocking rate. Utilization checks should also be made periodically throughout the grazing season to make certain that the stand is not being overused.

Compositional changes may occur in seeded stands that are grazed at the same season year after year. For example, continued heavy spring use of crested wheatgrass each year may weaken it to such an extent that it is unable to resist the invasion of native warm-weather growers such as blue grama and sand dropseed. Similar changes in composition may take place during years when winter and spring moisture is extremely low and summer rainfall abundant. In 1950 and 1951, when these conditions prevailed, both blue grama and

sand dropseed increased greatly in several crested wheatgrass stands. Occasional rest from spring grazing may help to prevent undesirable shifts in composition.

Even Utilization of Seeded Stands

Wide variations in utilization commonly occur even on relatively small seeded areas. Overusing one part of a stand while underusing another because of poor livestock distribution is not only inefficient and wasteful but may injure or destroy the plants on the overgrazed areas. Poor distribution can be held to a minimum by fencing, water development, salting, and riding. Some administrators and stockmen have found it feasible to haul water to their livestock and to change watering places and salt grounds at frequent intervals in order to get the most even and efficient utilization of their seeded stands.

Experience has shown that livestock will often concentrate their grazing on a seeded stand and ignore adjacent available native forage. This is especially true when native plants are dormant and dry but the seeded species are green and succulent. Under such conditions, seeded openings must either be fenced and managed as separate units, or if left unfenced, the use must be based primarily on the grazing capacity of the seeded area.

Costs and Returns

Cost and benefits of seeding are both direct and indirect (*31*). Direct costs include outlay for site preparation, seed, planting, fencing, and in some cases the development of new water facilities. Indirect costs include such items as interest on investment and loss of grazing use during the period required for the establishment of the seeded stand. Since some failures are inevitable, risk should also be included as an indirect cost.

Direct benefits of seeding consist of such obvious values as more and better forage production with decreased supplemental feeding, and improved condition of animals including more salable meat and wool products. The indirect, less easily evaluated benefits may include a more compact operation with reduced costs in handling the livestock, reduction of noxious and poisonous plants, and reduction of soil erosion.

Because costs and returns are so greatly affected by location, site conditions, facilities for doing the work, wage scales, and other variable factors, records from any particular planting can only be applied in a general way to other areas. Values are given in figure 15 for a U. S. Forest Service planting of 2,200 acres of crested wheatgrass on the Carson National Forest in northern New Mexico. This planting was started in 1949 and completed in 1950.

Figure 15 shows some of the more important seeding costs that must usually be considered and, for this particular planting, their proportion of the total cost. The largest single cost was for site preparation, $3.09 per acre. Equipment-repair cost for this particular project, $1.94 per acre, was unusually high; about $1.25 per acre is a more representative figure (*1*). Cost for crested wheatgrass seed planted at an approximate rate of 5 pounds per acre was 98 cents per acre;

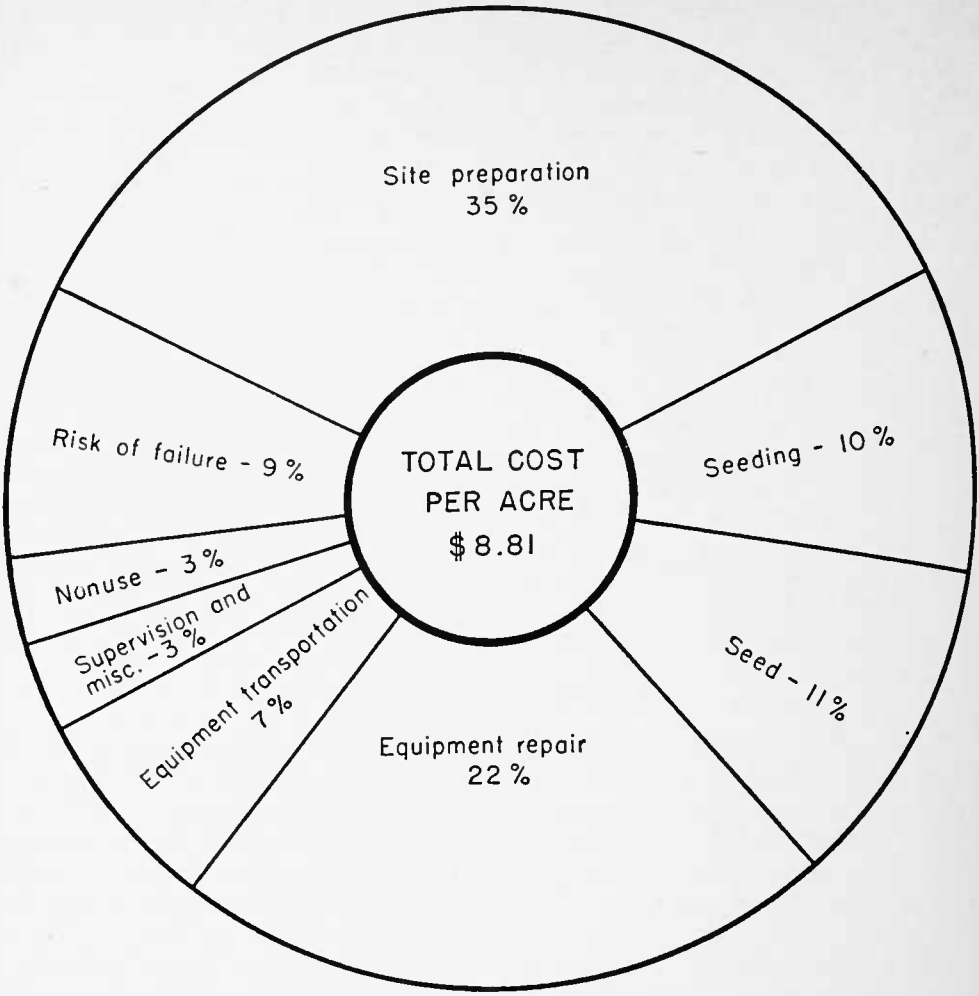

FIGURE 15.—Distribution of planting costs for a 2,200-acre range seeded to crested wheatgrass in northern New Mexico, 1949–50.

drilling, 84 cents; equipment transportation, 66 cents; and supervision and miscellaneous, 23 cents.

Because slightly less than 10 percent of all seeding on national-forest lands in the Southwest has required replanting, a charge of 80 cents per acre (9 percent of the total seeding costs) is made for risk. The value of the native forage lost during the 2 years when the seeded range was closed to grazing to insure successful establishment was estimated to be 27 cents per acre. This was based on actual forage measurements and a commercial value for the range forage of $3 per cow month of grazing. In addition to the above costs, fencing is often required in order to make the most effective use of a seeded area. However, such cost cannot be charged entirely to seeding because fencing might also be necessary for proper livestock control on the native range.

Grazing use of this planting was begun the third year after seeding. During that year, 400 cattle were turned into the seeded stand early in May and kept there for 6 weeks. At a stocking rate of 3.9 acres

per cow month, less than 25 percent of the current spring herbage was utilized. In addition to grazing, 10,000 pounds of seed was harvested from 94 acres of the planting, averaging 106 pounds to the acre.

Results of 5 years of measurements on other crested wheatgrass stands indicate that 3 acres of crested wheatgrass, when moderately grazed at 50 percent or less utilization, will easily provide a month's grazing for a cow in the southwestern ponderosa pine zone. Assuming a longtime average of 3 acres of crested wheatgrass needed per cow-month of grazing and a common commercial value of $3 per cow-month of pasturage, the annual return from grazing on this planting is $1 per acre compared with 13½ cents per acre from nearby native range. No attempt is made to evaluate the many other benefits that will be obtained from this planting. Some of these benefits are a balanced forage supply and early green feed; an improved higher native range brought about by a reduction in early spring grazing pressure; and an improved, protective soil cover.

The potential productivity of the land rather than its current market value, should be the basic criteria for seeding. For example, on some sites and under some conditions as much as $20 per acre might be a good investment. Again, on poor sites and where seeding cannot help much with critical forage needs, even $4 per acre would be a poor investment unless other benefits such as erosion control and watershed improvement justified most of the cost.

Seeding is only one of the ways of improving rangelands. Before attempting any extensive, costly seeding work, therefore, the possibilities of improving the native range through better management practices should be carefully considered. And even seeding should be done as part of an overall range-management plan whereby not only the seeded area but the native range as well is improved and properly managed.

SEEDING FOR SOIL PROTECTION ON BURNED OR DISTURBED TIMBERLANDS

Site protection against erosion is of the utmost importance in the interest of future timber production on areas where it takes 20 to 30 years to get adequate, natural restocking of ponderosa pine (*32*). Even where tree planting is used to hasten reforestation, some herbaceous cover is needed to hold the soil until the trees can stabilize the site. In addition, herbaceous cover affords protection to young pine seedlings against evaporation, temperature extremes, and other adverse physical conditions. On the other hand, it offers competition.

Competition always occurs where two or more plants make demands on the same water, nutrients, or light energy in excess of the supply. The most successful individuals suppress the weaker ones and as a result the latter are dwarfed or die (*43*). Vegetation also modifies the microclimate and soil conditions and makes them more favorable for some of the plant competitors (*6*). By recognizing and applying these basic principles, seeding can be a useful tool for encouraging maximum sustained timber production as well as for watershed and forage improvement.

The compact clay subsoils exposed on many deteriorated timberlands are unfavorable for pine establishment (*32*), because of de-

ficiences in moisture, nutrients, and aeration. These poor soils, compared with the better soils of comparable sites that have been protected by a herbaceous cover, result in slower tree growth and less timber production (*33*). A seeded herbaceous cover protects the soil against erosion and deterioration, and it may even improve soil conditions while pine is becoming established. Infiltration is increased, often making more moisture available for plant growth.

That herbaceous vegetation is both beneficial and detrimental to pine reproduction in this region was shown by Pearson (*32*). A cover of native tall grasses or forbs favored pine germination and establishment the first year through protection against excessive insolation, wind, winterkilling, and frost heaving. After the first year, these benefits were counterbalanced by competition for soil moisture and in some cases light, which slowed the growth of the pine seedlings and increased their mortality rate. Pine reproduction generally succeeded, despite competition from the herbaceous plants, unless the latter were of unusual density and luxuriance.

The fact that growth rate and survival of pine reproduction were considerably better on grazed areas suggests regulated grazing as a practical means of controlling herbaceous competition. This was also implied in later studies (*34*) in which Pearson found that clipping the native grasses materially increased pine seedling survival in comparison with undisturbed grass plots, and gave results roughly equivalent to an initial surface scalping. Best survival, of course, was found on areas kept continuously free of competing vegetation. He also found that spring-growing species, such as Arizona fescue, offered more competition to pine seedlings than grasses that remained dormant until the beginning of summer rains.

On the Metz Mountain burn, ponderosa pine seed was planted in 2-year-old seeded stands of herbaceous vegetation representing a variety of species and densities. Germination of the pine seed was unaffected by either the kind of herbaceous vegetation or differences in basal densities. At the end of the second growing season, ponderosa pine seedlings survived in 51 percent of the seed spots. Pine seedling survival tended to be inversely related to the total basal density of the herbaceous vegetation (fig. 16), but there was no apparent relation between pine seedling survival and the weight of herbage produced. Where the competing herbaceous seeded and native vegetation was completely eliminated by scalping and kept suppressed by subsequent weeding, seedlings survived in 90 percent of the seed spots.

Although herbaceous vegetation, seeded and native alike, adversely affects pine seedling survival, fairly good survival has been obtained in spite of this competition. Moreover, the indications are that adapted grasses and forbs seeded on disturbed timberland sites offer no greater obstacle to pine regeneration than does natural revegetation. Even though pine reproduction may often be inhibited by a vegetative cover, it is questionable whether an attempt to maintain large areas of bare soil to expedite reforestation is either practical or desirable. This is especially true where sources of tree seed are inadequate. Small areas disturbed in logging operations may not need treatment to restore vegetative cover where erosion hazards are not great.

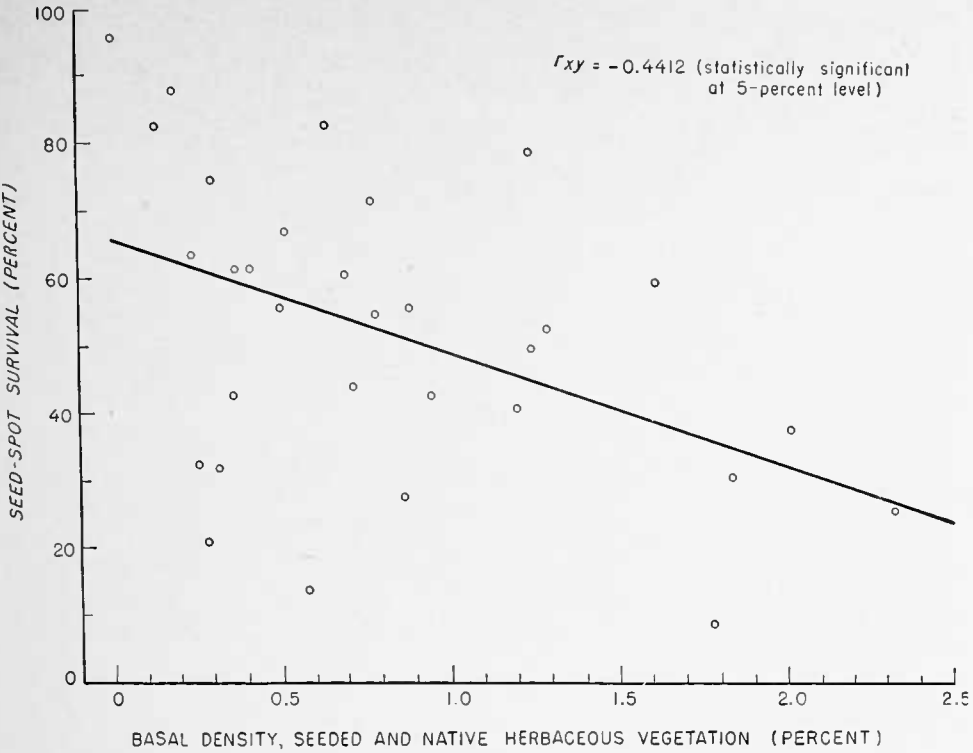

FIGURE 16.—Relation between ponderosa pine seedling survival and basal density of herbaceous vegetation for seed spots planted in 2-year-old seeded stands of herbaceous vegetation at the Metz Mountain burn.

SELECTING THE SITE

Recent burns, on which the vegetation and litter have been largely destroyed by fire and the ground surface left covered with a layer of loose ash, are good seeding sites that do not require further seedbed treatment (fig. 17). Older burns, though less favorable, provide satisfactory seedbeds as long as the soil surface is relatively free of weeds and loose enough that the seed will become adequately covered.

Timbered areas disturbed by logging operations or by construction work to such an extent that native vegetation has been largely destroyed make good seeding sites providing the bared areas are seeded before they are reinvaded by weedy plants (fig. 18). This condition often exists along abandoned logging roads. Such sites usually require the construction of water bars and drainage structures in advance of seeding for effective control of soil movement. Seeding is not recommended for such sites when the ground has been only lightly disturbed and much of the original plant cover remains.

Trials on the Coconino Sales area in northern Arizona provide evidence that a large amount of soil disturbance with the attendant elimination of native plant competition is necessary for good seeding results (fig. 19). Unsatisfactory stands resulted where seed was broadcast on sites with 50 percent or less soil disturbance, and satisfactory stands were obtained where 75 percent or more of the soil was disturbed.

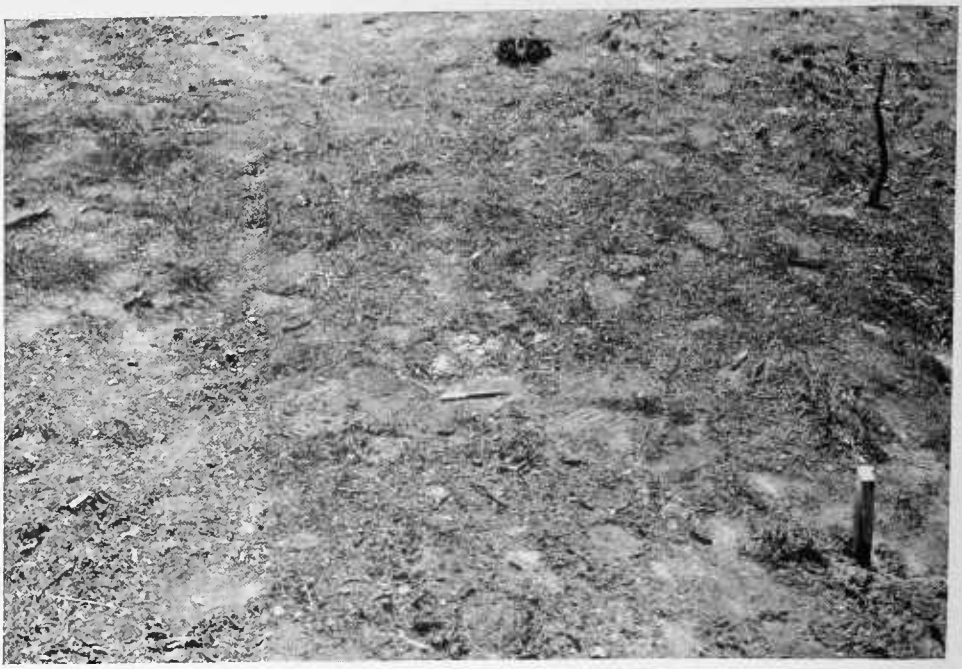

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FIGURE 17.—This ground surface of a recent burn, on which all native vegetation has been completely destroyed and a layer of loose ash left, is a favorable site for seeding.

The feasibility of seeding must be judged individually for each disturbed site. For example, on skid trails where the soil has not been sufficiently disturbed to eliminate an adequate amount of native vegetation, seeding results would probably be poor. On such areas, drainage structures to prevent erosion together with protection from livestock grazing to promote natural recovery is probably the best method for restoring a satisfactory cover.

SPECIES ADAPTED FOR SEEDING

Tests of more than 40 species have been made on disturbed ponderosa pine timberlands. The 20 best adapted for seeding are shown in table 6.

Selection of species for a specific planting depends on the site characteristics and the purpose of the planting. Thus to obtain erosion control, a quick and effective cover is of greatest importance. The need on other sites may be for species able to become established and grow on a poor seedbed or with a minimum of grazing protection. On many plantings length of life of the seeded species, the competition the species gives to ponderosa pine regeneration, or the likelihood of losing the seed by washing must be considered. A sufficient number of adapted species with the characteristics required for seeding on the various kinds of disturbed timberland sites are available to meet most needs. Table 7 presents a generalized summary of the important characteristics of the adapted species.

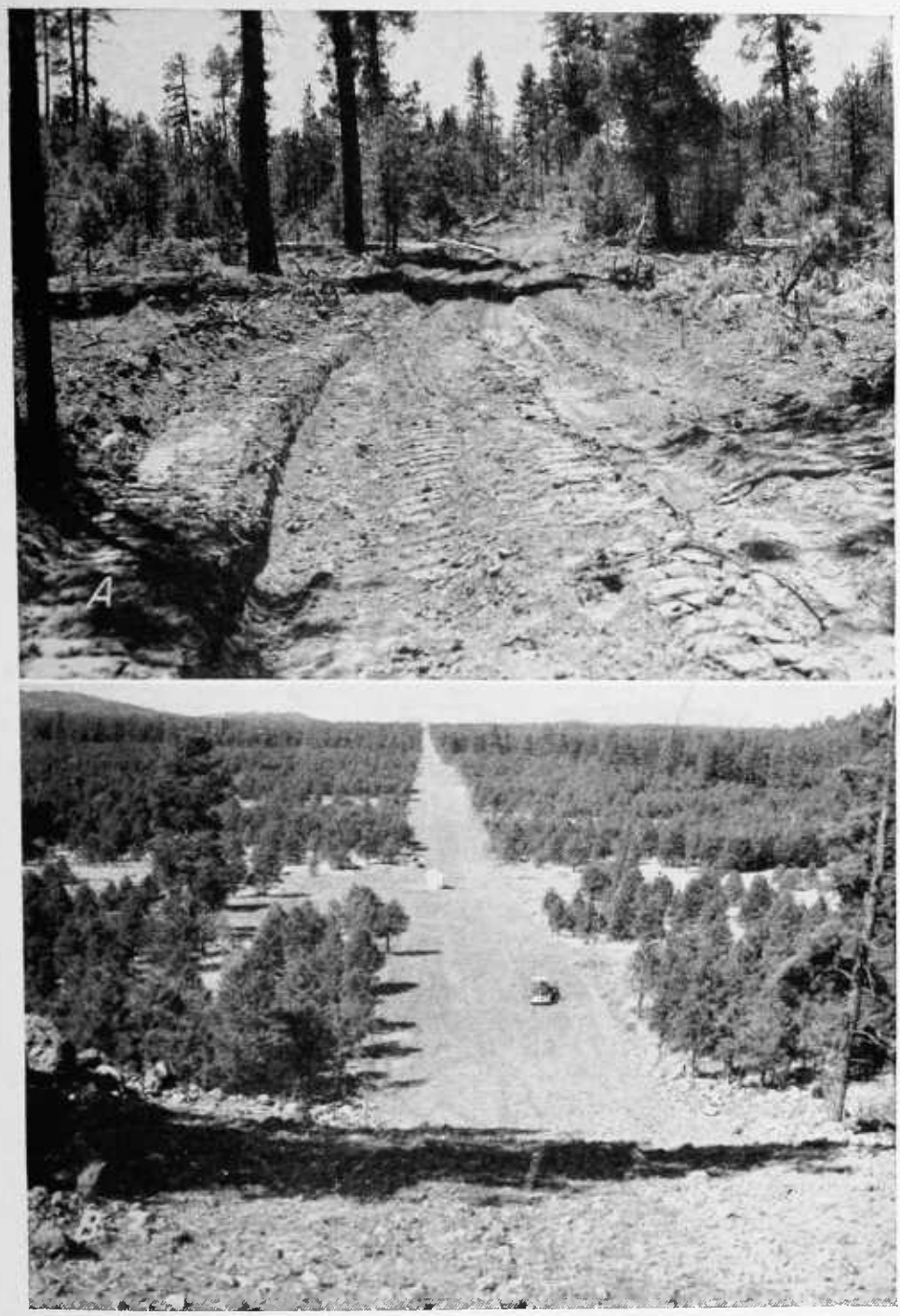

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FIGURE 18.—*A*, A logging road shortly after abandonment. For the most effective control of soil movement, water bars and drainage facilities should be constructed and the site seeded. *B*, Timberland disturbed by the laying of a natural-gas pipeline. Seeding would protect this expensive investment against erosion, and because of the necessity for pipeline maintenance, grass is more desirable than trees on this disturbed area.

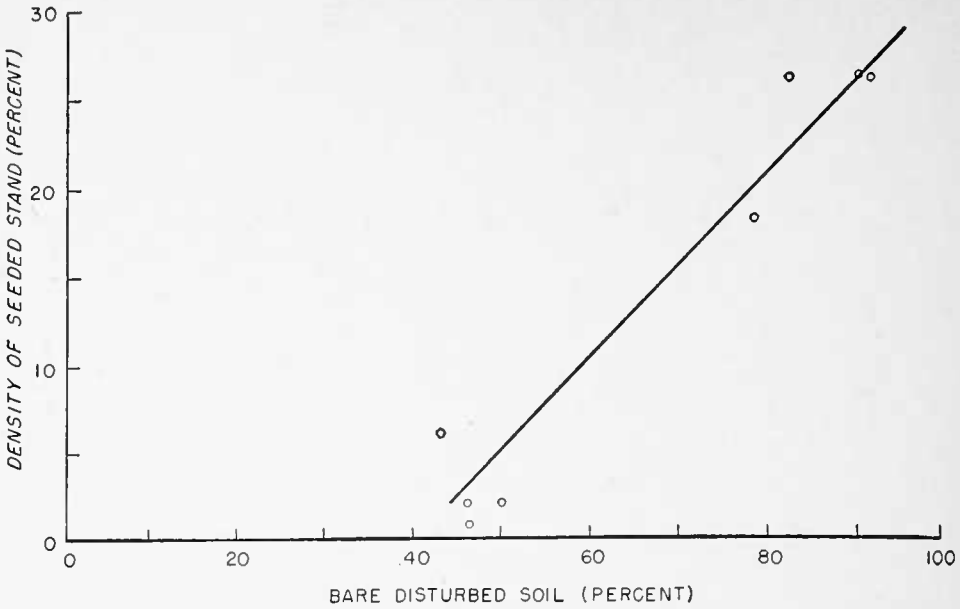

FIGURE 19.—Relationship between degree of soil disturbance in a logging operation and subsequent success of seeded grasses. (Coconino Sales area.)

On logging roads used intermittently, and on drainageways, the long-lived sod-forming grasses such as intermediate wheatgrass and smooth brome will give maximum soil protection and can re-establish themselves more easily after repeated disturbances.

On critical areas where erosion control is the primary purpose of the planting, species should produce either a dense ground cover, a large volume of herbage, or better still, a good combination of both (*30*). Outstanding in this respect are intermediate wheatgrass, orchardgrass, and tall wheatgrass among the long-lived perennials, and slender wheatgrass, Canada wildrye, and blue wildrye among the short-lived perennials (table 8). Of the annuals, black mustard is best because of the large amount of herbage it produces. All of these species, with the exception of the mustards, can also be utilized as forage by both livestock and wildlife. The annuals and short-lived perennials are useful for temporary cover until pine reforestation can be accomplished.

On steep slopes or easily eroded soils, quick initial protection against soil erosion is especially important. The annual mustards grow rapidly on burns and produce a dense initial cover. Although these plants die at the end of the first growing season, they leave a large amount of litter that gives some soil protection the second year (fig. 20). Volunteer seeding is poor. Perennial grasses start much more slowly the first growing season but provide better cover by the second growing season (table 8).

There is a possibility of using a combination of a fast-starting annual and a slower starting perennial, such as black mustard and tall wheatgrass, to achieve both a rapid initial and a long-lasting protective cover. Preliminary tests of such mixtures are promising. Also, a mixture of yellow sweetclover and crested wheatgrass has given

TABLE 6.—*Relative success* [1] *of species adapted for seeding disturbed timberlands, as affected by site differences*

Species [2]	Burn plantings				Logged-over land plantings			
	Recent			Year old	Logging road	Skid trail	Roadside strip	
	Barney pasture	Metz Mt.	A–1 Mt.	A–1 Mt.	Coconino Sales	Coconino Sales	Coconino Sales	Little Mt.
Long-lived bunchgrasses:								
Bluegrass, big			F	E	F		P	P
Orchardgrass		E	G	E		G	G	
Crested wheatgrass	F	F		G	G	F	G	F
Tall wheatgrass		E		E			E	G
Wildrye, Russian		P		G				O
Long-lived sodgrasses:								
Brome, smooth	F	F	F	G		F	G	F
Western wheatgrass		G		G				F
Intermediate wheatgrass		E		E	G	G	G	G
Short-lived bunchgrasses and legumes:								
Oatgrass, tall		F	F	E			VP	
Mountain rye		F		E	F		F	
Winter rye	F	F		G				P
White sweetclover		P	G	G	VP		O	P
Yellow sweetclover			E					
Slender wheatgrass		G						
Primar slender wheatgrass			E	E				
Blue wildrye			G					
Canada wildrye			E					
Annuals:								
Black mustard			E					
India mustard			G					
White mustard			E					

[1] Relative success: E=Excellent; G=Good; F=Fair; P=Poor; VP=Very poor; O=Failure; where success rating is not given, there were no tests.

[2] Seeded stands range from 3 to 6 years in age.

TABLE 7.—*Characteristics of species adapted for seeding disturbed timberlands* [1]

Species	Quick erosion protection value	General erosion protection value	Seedling vigor	Seed resistance to washing	Palatability
Long-lived bunchgrasses:					
Big bluegrass	F	F	P	P	F
Orchardgrass	F	G	G	F	E
Crested wheatgrass	P	F	F	P	F
Tall wheatgrass	F	G	G	G	P
Russian wildrye	P	F	P	F	F
Long-lived sodgrasses:					
Smooth brome	F	F	F	P	G
Western wheatgrass	P	G	F	F	F
Intermediate wheatgrass	F	E	G	G	G
Short-lived bunchgrasses and legumes:					
Tall oatgrass	F	F	F	P	F
Winter rye	F	F	F	G	F
Mountain rye	F	F	F	G	F
White sweetclover	F	F	F	G	F
Yellow sweetclover	F	F	F	G	F
Slender wheatgrass	F	G	G	G	F
Blue wildrye	F	G	G	F	F
Canada wildrye	F	G	G	F	F
Annuals:					
Black mustard	E	G	G	G	(2)
India mustard	G	F	G	G	(2)
White mustard	G	F	F	G	(2)

[1] E=Excellent; G=Good; F=Fair; P=Poor.
[2] No palatability.

good results on one large-scale planting (fig. 21). However, yellow sweetclover is a biennial that starts growth more slowly than annuals such as the mustards. In using mixtures of species with different initial growth rates, there is always the danger that the faster starting annual species may use most of the soil moisture during the dry periods of the first year and cause the death of the slower starting perennial (*38*).

Pine burns, cutover lands, and other disturbed areas require species that are easily established without intensive site preparation, because site conditions following disturbances often prevent thorough tillage. One author suggests that the failure of larger seeded species used in broadcast seeding on burns in northern Idaho was caused by the seed not being covered (*9*). However, results obtained in the Southwest, indicate that seedling vigor is probably an even more important factor than coverage. Species that have proved most easily established on disturbed timberlands, without special tillage or covering, include among the perennials intermediate, tall, and slender wheatgrass; orchardgrass; blue wildrye; and Canada wildrye; and, among the annuals, black and India mustard.

F-472082

FIGURE 20.—This 10-week-old stand of India mustard, seeded on a burn, gave good initial protection against erosion. Although it died out at the end of the first growing season, the large amount of litter gave some protection the second year.

TABLE 8.—*Comparative value of species used in seeding for erosion control, as indicated by herbage yields and basal density* [1]

Species	Air-dry herbage yield per acre	Basal density
Metz Mountain burn:		
Long-lived perennials:	*Pounds*	*Percent*
Intermediate wheatgrass	950	0.42
Tall wheatgrass	890	.40
Orchardgrass	410	1.16
Western wheatgrass	300	.22
Smooth brome	230	.30
Crested wheatgrass	80	.22
Grimm alfalfa	20	.02
Short-lived perennials:		
Slender wheatgrass	870	1.40
Mountain rye	340	.22
Winter rye	330	.12
White sweetclover	310	.16
Tall meadow oatgrass	260	.20
A–1 Mountain burn:		
Short-lived perennials:		
Canada wildrye	640	.76
Primar slender wheatgrass	570	.95
Blue wildrye	305	1.29
Annuals:		
Black mustard	425	.21
India mustard	125	.09
White mustard	320	.10

[1] Measurements were made at the end of the first growing season for annuals and at the end of the second growing season for perennials.

F-478103

FIGURE 21.—A 2-year-old mixture of yellow sweetclover and crested wheatgrass seeded on 1,350 acres of ponderosa pine burn in northern Arizona. The fair stand of crested wheatgrass is obscured by the rank growth of yellow sweetclover. This critical slope was also contour furrowed as an additional mechanical aid in preventing erosion.

F-472096

FIGURE 22.—Seed washing is a serious problem on seeded burns. On this experimental plot, heavy washing of light chaffy big bluegrass seed resulted in the bare slope at the background and the concentration of plants in the depression.

Though successful plantings have been obtained on disturbed timberlands without complete grazing protection, some unsatisfactory plantings have resulted from excessive grazing and trampling. Where grazing use is unavoidable, seeding is feasible with species such as tall, crested, and slender wheatgrass; Canada and blue wildrye; and black mustard. These species are less readily eaten by livestock than others such as orchardgrass and smooth brome. Or, the more grazing-resistant rhizomatous species, such as western wheatgrass, can be used. All of these species have established satisfactory stands and maintained good vigor over periods up to 6 years in small-scale test plantings open to grazing on disturbed timberlands.

Seed washing is often a serious problem, especially in areas including steep, smooth slopes, and where torrential rains are common. Light chaffy or trashy seed are most susceptible to being floated off and washed away by runoff water (fig. 22). This danger can be decreased by using species that have clean, heavy seed and resist movement, such as tall, intermediate, and slender wheatgrass; black mustard; sweetclover; and mountain rye. Special cleaning treatment to reduce chaffiness might also be well justified.

Methods For Establishing A Protective Herbaceous Cover

Ponderosa Pine Burns

Grasses and forbs can be seeded most easily and effectively on ponderosa pine burns by broadcasting the seed onto the fresh, loose ash. Other methods of planting are usually not practical because of the large numbers of standing dead trees, the debris, the rough topography, or the rocky soil. Burns that are allowed to remain untreated are commonly subject to soil compaction and erosion, and they eventually are invaded by a weedy cover that is usually of low erosion-control and forage value and in addition interferes with the establishment of any artificially seeded vegetation (fig. 23). On older burns, satisfactory seeding by broadcasting alone can only be accomplished where the ground is still free from weedy competition and enough loose ash remains to furnish a good seedbed. Because few burns retain these conditions for as long as 1 year, they should be seeded as soon as possible after the fire.

Since mechanical seed coverage on most pine burns is usually not practical, species that do not require thorough coverage for good establishment give best results. A test of 11 species planted on a fresh burn at Metz Mountain indicated that the need for mechanical coverage, as shown by a comparison of seed coverage by hand raking with natural coverage in fresh ashes, varied among individual species. Although the number of plants established was consistently better when raking followed broadcasting, this was not always true for basal density and herbage yield, and there were significant differences for individual species. Table 9 shows the 11 seeded species arranged approximately in decreasing order of success in the unraked plantings, as indicated by basal densities and herbage yields. These results show that mechanical seed coverage on fresh pine burns is beneficial, but for many species not enough so to justify the increased cost of this practice.

F-472092, 472094

FIGURE 23.—*A*, An untreated burn 7 years after the fire, occupied by a sparse cover of weeds that provide only poor site protection and greatly reduce chances for seeding success. One of the weeds is bracken, a rhizomatous species that will eventually occupy the entire site and offer severe competition to pine reproduction. *B*, A stand of slender wheatgrass planted in the fresh ash immediately after a burn, which is providing good soil protection and preventing weed invasion at the end of the second growing season.

Hand-broadcast seeders are well suited for use on small burns and larger, irregular burns where spot seeding is necessary. However, on large, uniform areas, airplane seeding is more efficient (*5*). Costs of airplane seeding compared with those of hand planting on pine burns

TABLE 9.—*Effects of covering seed by hand raking on basal density, herbage yield, and plant establishment for a ponderosa burn at Metz Mountain*

Species	Basal density [1]		Air-dry herbage yield per acre [1]		Plants per square foot [1]	
	Raked area	Area not raked	Raked area	Area not raked	Raked area	Area not raked
	Percent	*Percent*	*Pounds*	*Pounds*	*Number*	*Number*
Slender wheatgrass	1. 40	1. 40	840	880	4. 2	2. 3
Orchardgrass	. 46	1. 16	300	410	1. 9	1. 1
Intermediate wheatgrass	. 76	. 42	1, 360	950	2. 9	1. 6
Tall wheatgrass	. 58	. 40	880	890	1. 1	. 6
Mountain rye	. 58	. 22	1, 110	340	. 6	. 3
Smooth brome	. 48	. 30	450	230	2. 0	1. 4
Western wheatgrass	. 28	. 22	240	300	3. 4	3. 3
Tall oatgrass	. 58	. 20	320	260	1. 0	. 4
White sweetclover	. 02	. 16	110	310	. 5	. 4
Winter rye	. 88	. 12	1, 000	330	1. 0	. 8
Crested wheatgrass	. 48	. 22	280	80	2. 5	. 6

[1] All counts and measurements made at the end of the second growing season.

are not available for the Southwest. In eastern Oregon, however, it was relatively inexpensive (*35*). These, airplane seeding costs were estimated to be only half that of hand broadcasting under normal conditions, and even less where labor is expensive.

Logging and Construction Disturbance

Ordinary farming equipment is not well suited for the seedbed preparation that is necessary on much of the disturbed timberlands in the ponderosa pine zone. It is impossible, for example, to use the commercial single-disk drill on the rougher steeper terrain, and even on gentle slopes the uneven ground surface results in only a small percentage of the seed being planted at the proper depth. Therefore, seeding is most practical where the seed can be broadcast on loose soil so that natural coverage by sloughing takes place. Drilling or other types of soil tillage are practical only where the ground is not too rough or steep and debris is not present in sufficient amounts to interfere with these operations. Proper drainage structures are usually needed to prevent seed washing and excessive erosion while the vegetative cover is becoming established. When possible, such structures should be installed before the planting is done.

Where the soil has been compacted by heavy equipment, settling, or washing, treatment to loosen the surface is necessary. A planting method, such as drilling, which will loosen the soil surface and distribute and cover the seed all in one operation is desirable. At the Coconino Sales area in northern Arizona 1 years after seeding, crested wheatgrass drilled into a highly compacted logging road produced 1.5 times as much protective vegetation as broadcast seeding followed by covering with slash, 1.7 times as much as broadcasting followed by

light harrowing, 1.7 times as much as broadcasting alone, and 28.3 times as much as natural revegetation.

Drilling should be done on the contour wherever feasible. Seeded stands established in drill rows running down the slope tend to concentrate runoff water between the rows and to decrease the effectiveness of erosion control. Therefore, on long narrow timberland disturbances such as abandoned roads, skid trails, or pipelines where drilling on contour is not possible, some other method of planting is preferred. For example, broadcast seeding and then covering with slash deserves more consideration in the artificial revegetation of logging roads and skid trails, because of its initial erosion-control value. This is especially true for the steeper slopes. In the beginning, the slash cover is more effective than the planting for checking erosion. Then as the slash gradually deteriorates, the established plants assume the major role in stabilizing the soil.

Broadcast seeding proved valuable for supplying a protective cover on roadside strips disturbed by mechanical slash cleanup at the Coconino (fig. 24) and Little Mountain Sales areas in northern Arizona. This method alone was effective since the soil surface was loose over most of the area at the time of planting. Stand densities averaged six times as great for spot seeding after mechanical slash cleanup as for seeding before cleanup. Where plantings are made after mechanical slash piling, the best seeding sites can be easily detected and no seed is wasted on undisturbed soil. Moreover, the danger of seed being destroyed in slash-burning and by being buried too deeply during the cleanup operation is also avoided.

Seeding Rates and Proper Time for Planting

The same seeding rates and standards of seed quality recommended for pine openings in table 5, p. 24, are also suitable for disturbed timberlands. In addition, black, India, and white mustard have been seeded successfully at a seeding rate of 5 to 6 pounds per acre. The minimum rates are for good seedbeds and for an intensive method of planting, such as drilling. Under less favorable conditions, the higher seeding rate should be used. Seed purity for black and India mustard, 97 percent; and seed germination, 85 percent. Seed purity for white mustard, 95 percent; and seed germination, 90 percent. These rates are similar to those used in California for burned brushlands (*15*).

The planting time for disturbed timberlands must be correlated both with favorable moisture conditions and the period when the disturbance occurs. Careful advanced planning is therefore necessary for successful seeding and greatest efficiency.

Forest fires in the Southwest mainly occur during the hazardous dry spring period of April, May, June, and sometimes early July. Ideally, these fresh burns should be planted immediately preceding the first dependable summer moisture. Seed planted earlier may germinate following light spring showers, which are too scanty to maintain the seedlings until the more dependable summer rains. Plantings made after the summer rains have begun are usually handicapped by compacted and eroded soils and sometimes by weed competition. In addition they lose the benefit of part of the summer moisture, thus making less growth the first season, an important factor both for initial soil protection and plant survival. For all

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FIGURE 24.—Roadside strips bared of herbaceous vegetation in the process of mechanical slash cleanup can be successfully seeded for soil stabilization and improvement, to keep out undesirable weeds and maintain a low fire hazard, to provide forage for livestock and wildlife, and to improve esthetic values. *A*, A disturbed roadside strip at the Coconino Sales area in northern Arizona, which is being broadcast to tall wheatgrass. *B*, The same site 2 years after planting.

practical purposes, the best average planting period is between June 15 and July 1. Older burns still suitable for seeding are subject to the same conditions as fresh burns and should be planted during the same period.

Logging and construction activities are mainly carried on from the time the ground is dry in the early spring until heavy snowfall in the winter. The best period for planting will, therefore, depend in part on the time when the disturbance occurs. Here the aim should be to plant when chances for success without seedbed preparation are greatest. Thus, spring disturbances should be seeded just before the summer rains—June 15 to July 1—to take advantage of both favorable moisture conditions and a loose seedbed. Summer disturbances between July 1 and August 15 should be seeded as soon as possible after they occur. In this way the necessity for tillage because of soil compaction can usually be avoided. In locations where dependable, heavy snowfall occurs, fall plantings after September 15 can be carried on in the same manner as for the summer. On compacted sites where loosening of the soil surface is required, seeding should be done concurrently with tillage in the period between June 15 and August 15.

Grazing Management After Seeding

Guides presented for grazing seeded openings also apply in general to seeded timberlands.

Some satisfactory plantings have been obtained on disturbed timberlands in the Southwest without special protection from livestock. Others, however, have been severely damaged by excessive grazing and trampling during their early growth. To minimize the chances for failure, it is best to protect new plantings from grazing during the first 2 years whenever possible.

Seeded stands on sheep ranges can be managed by herding. On cattle ranges, however, studies in other areas (*14*) show that measures such as salting away from seeded areas, closing off stock water, fencing, riding, and changing the place where the cattle are turned into the range are usually necessary to get good cattle distribution. This is also true for the Southwest. Small, scattered seeded spots on logged-over lands can sometimes be initially protected by covering with slash. Also, the use of the less palatable or grazing-resistant species is a possibility for these areas. Larger seeded areas, such as burns, are often best and most easily protected and managed by fencing.

As mentioned earlier, the benefits of grazing to encourage pine seedlings on disturbed timberlands deserves consideration. Pearson (*32, 34*) found that clipped grasses and forbs used less moisture than unclipped ones and that moderate to close grazing increased pine seedling survival unless pine browsing was too severe. Preliminary evidence indicates that grazing may be even more effective for the control of seeded stands on disturbed timberlands than for natural revegetation, since many of the species used for seeding are more readily grazed than most of the native weedy invaders. Pearson (*34*) cautioned that grazing to the point of denudation is not advisable because it results in browsing of pine seedlings, erosion on the slopes, and the packing of soil in the valleys.

COMMON AND BOTANICAL NAMES OF SPECIES MENTIONED

Trees

Douglas-fir	*Pseudotsuga menziesii*
Firs, true	*Abies* spp.
Juniper	*Juniperus* spp.
Oak, Gambel	*Quercus gambelii*
Pine, limber	*Pinus flexilis*
Pine, pinyon	*P. edulis*
Pine, ponderosa	*P. ponderosa*
Spruces	*Picea* spp.

Herbaceous Plants

Alfalfa, Grimm	*Medicago sativa* hort. var. GRIMM
Alfalfa, Ladak	*M. sativa* hort. var. LADAK
Bluegrass, big	*Poa ampla*
Bluegrass, Kentucky	*P. pratensis*
Bracken	*Pteridium aquilinum*
Brome, mountain	*Bromus carinatus*
Brome, smooth	*B. inermis*
Canarygrass, reed	*Phalaris arundinacea*
Fescue, Arizona	*Festuca arizonica*
Fescue, tall (or reed)	*F. arundinacea*
Goldenpea, pine	*Thermopsis pinetorum*
Grama, blue	*Bouteloua gracilis*
Muhly, mountain	*Muhlenbergia montana*
Mustard, black	*Brassica nigra*
Mustard, India	*B. juncea*
Mustard, white	*B. hirta* (=*B. alba*)
Muttongrass (or mutton bluegrass)	*Poa fendleriana*
Oatgrass, tall	*Arrhenatherum elatius*
Orchardgrass	*Dactylis glomerata*
Redtop	*Agrostis alba*
Rye, mountain	*Secale montanum*
Rye, Michel's hybrid winter	*S. cereale*
Squirreltail, bottlebrush	*Sitanion hystrix*
Sweetclover, white	*Melilotus alba*
Sweetclover, yellow	*M. officinalis*
Thistles	*Cirsium* spp.
Timothy	*Phleum pratense*
Wheatgrass, beardless	*Agropyron inerme*
Wheatgrass, bluebunch	*A. spicatum*
Wheatgrass, western (or bluestem)	*A. smithii*
Wheatgrass, crested; also called Standard crested wheatgrass	*A. desertorum*
Wheatgrass, intermediate	*A. intermedium*
Wheatgrass, Primar slender	*A. trachycaulum* hort. var. PRIMAR
Wheatgrass, pubescent	*A. trichophorum*
Wheatgrass, slender	*A. trachycaulum*

HERBACEOUS PLANTS—Continued

Wheatgrass, tall ..... *A. elongatum*
Wildrye, blue ..... *Elymus glaucus*
Wildrye, Canada ..... *E. canadensis*
Wildrye, Russian ..... *E. junceus*

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